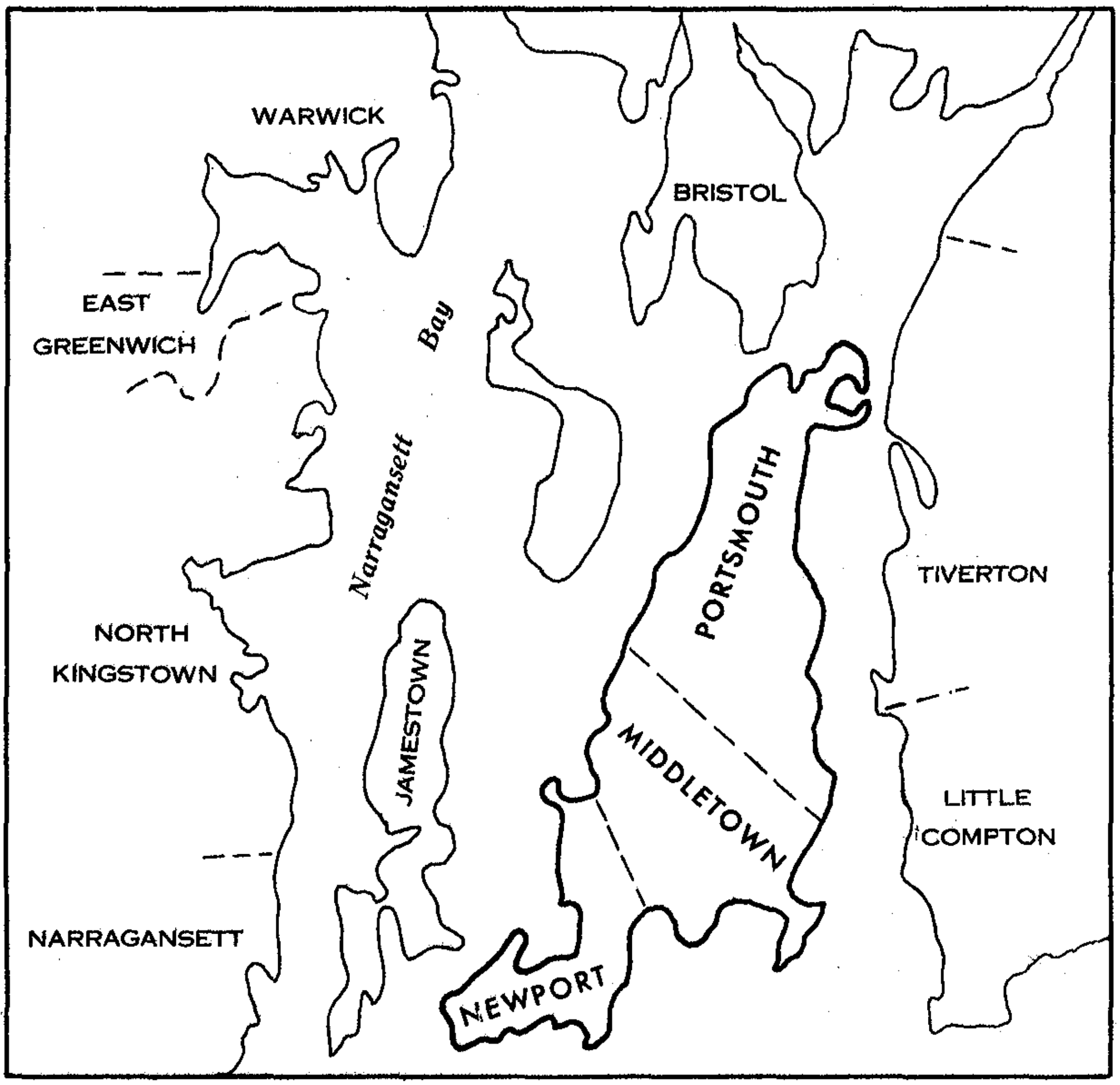
AQUIDNECK ISLAND, RHODE ISLAND
WATER SUPPLY STUDY



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

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AQUIDNECK ISLAND, RHODE ISLAND
WATER SUPPLY STUDY

Prepared by

NEW ENGLAND DIVISION
CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

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SUMMARY

This water supply study, undertaken at the request of the Rhode Island Water Resources Board, was conducted under the authority contained in Section 22 of the Water Resources Development Act (PL 93-251).

The purpose of this engineering feasibility study is to outline possible courses of action that could be undertaken in resolving what is projected to be a problem of some major importance in the supplying of water to Aquidneck Island. It is the intent that this report be closely scrutinized and reviewed by all those interests who are concerned in this matter.

The report deliberately excludes the recommendation of any of the alternative plans which were investigated and are documented herein. The reasons for such action were: 1) no assessment of the social, environmental, legal, and institutional impacts of the proposed alternatives were evaluated, and 2) the selection of a recommended plan would be the end result of a comprehensive review and possible further detailed investigations which are expected to follow.

Although this report makes no specific recommendations as to the alternatives developed, certain insight as to the probable steps necessary to meet the water supply requirements of the study area are readily apparent. As an instance, the time is certainly appropriate to begin serious consideration of those means by which current and projected water supply requirements can be satisfied. Essentially, population growth, both historical and projected, coupled with water demands experienced in some systems serving the study area which have forced the curtailment of supply, has placed, and will continue to place, greater demands on the area's water resources. This report, which addresses existing water supply source capabilities, future population served, and water supply demands, possible sources of additional water supplies, and the facilities required for their development, as well as estimates of construction and operational costs, is expected to provide a basis for the undertaking of more thorough, investigative study of the most feasible components of the alternatives developed.

Projections of the population served by municipal water systems and the water supply requirements expected by the years 1990 and 2020 were developed in the study. Total projected demand requirements are expected to increase from a present (1974) average daily water usage of about 11.2 mgd to approximately 14.4 mgd in 1990, and 20.4 mgd by the year 2020. These demands are reflected by an increase in

the population served from a level of about 97,120 in 1974, to approximately 116,800 in 1990, and 141,000 by the year 2020.

Alternative plans for additional water investigated off-island supply sources located in the proposed Big River Reservoir complex in the Pawtuxet River Basin, and groundwater supplies located in the upper Pawcatuck River Basin. Desalination facilities for the conversion of sea water into drinking water were also addressed. Facilities required to convey additional water from the alternative sources were designed and cost estimates prepared.

Estimated total project costs, average annual costs, and the cost to produce water proposed in the four alternatives developed in the study resulted as follows:

	Estimated Project Cost	Average Annual Cost	Cost of Water per 1,000 Gal.
Alternative No. 1 - Big River via Bristol County	$25,317,000	$ 2,103,000	$ 1.86
Alternative No. 2 - Big River via Jamestown	38,903,000	3,070,000	2.71
Alternative No. 3 - Groundwater	30,641,000	2,394,000	2.12
Alternative No. 4 - Desalination	30,256,000	6,272,000	5.55

AQUIDNECK ISLAND, RHODE ISLAND
WATER SUPPLY STUDY

I. INTRODUCTION

Background

Providing an adequate future water supply for the Aquidneck Island communities of Newport, Middletown, and Portsmouth has been a matter of concern for state and municipal officials charged with the responsibility of assuring the public's well being. If the Island is to remain an attractive and desirable area for people to live and work, and to enjoy the many recreational benefits the region has to offer, an adequate and dependable water supply should be provided.

Water supply on the Island prior to 1973 faced pressures from the demands of an expanding population and the needs of the various United States naval installations located there. The city of Newport's Department of Water, which supplies most of the municipal water on the Island, experienced demands, which at times, strained the system virtually to its maximum available capacity. Since then, however, the closing of most naval installations on the Island has resulted in greatly reduced demands upon existing water supply resources.

The latest predictions of population and economic development for the Aquidneck Island communities appear to indicate that the demands for water experienced in the early 1970's will probably not be equalled again until about the year 1990. If this is so, then existing surface supply sources should be adequate to meet the area's needs for the near future. This is not to say, however, that the future water supply needs of the Island are completely served. On the contrary, the limited yield of the existing reservoirs will not be sufficient to meet the needs of the area much beyond the late 1990's if current population and demand projections for the area prove to be correct. The available safe yield of existing supply sources is fairly well fixed and additional local sources on the Island to meet future demands are virtually nonexistent. Although nothing like a "crisis" situation faces the Island's water supply resources at the present time, there is little question that the situation could be significantly altered if a regional approach for water supply development is not undertaken.

Authority

At the request of the Rhode Island Water Resources Board, the U.S. Army Corps of Engineers, New England Division, was asked to provide technical assistance to the State of Rhode Island in a cooperative investigation of the water supply needs of the Aquidneck Island area, including the possibility of desalting.

Provisions for assistance by the Corps in such a joint venture are contained in Section 22 of the Water Resources Development Act (PL 93-251) which reads in part:

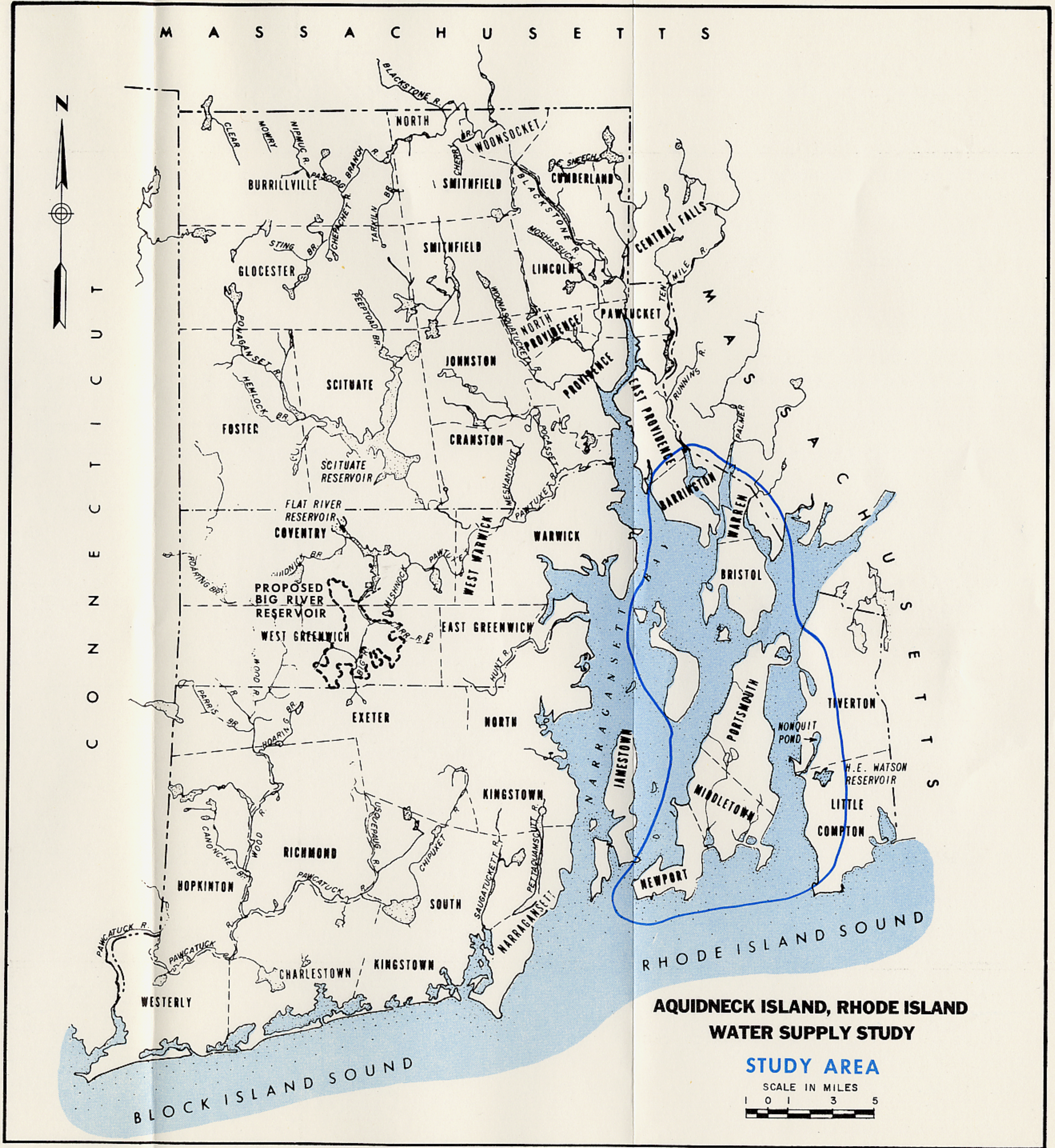
> "(a) The Secretary of the Army, acting through the Chief of Engineers, is authorized to cooperate with any state in the preparation of comprehensive plans for the development, utilization, and conservation of the water and related resources of drainage basins located within the boundaries of such state and to submit to Congress reports and recommendations with respect to appropriate federal participation in carrying out such plans."

Study Area

The study area, shown on Plate 1, includes the Aquidneck Island communities of Newport, Middletown, and Portsmouth. However, in order to determine the overall extent of water supply requirements for the entire region, the upper Narragansett Bay communities of Barrington, Warren, and Bristol were also included in the study. The study area is a portion of the Water Resources Board's designated Southern-South Central - Eastern Area Planning Region.

II. PURPOSE

This report was prepared for the Rhode Island Water Resources Board (WRB) as part of its comprehensive planning program. The study examined the water supply situation on Aquidneck Island based upon data contained in prior studies and engineering reports and also presents more detailed recommendations as a result of subsequent developments. Data for the preparation of this report was obtained from several federal and state agencies as well as local municipal officials.



AQUIDNECK ISLAND, RHODE ISLAND
WATER SUPPLY STUDY

STUDY AREA

The study attempted to explore, as thoroughly as possible, engineering alternatives for an adequate water supply to serve Aquidneck Island in view of increased demands projected for the future. The scope of the study included identification of water resources available to meet the 1990 and 2020 water supply needs of the study area; identification of alternative solutions to meet these needs including the necessary facilities; preparation of generalized cost estimates for the alternative solutions; and comparison of the physical and economic feasibility of the alternatives derived.

The alternative solutions presented in this report are based upon preliminary engineering studies of sufficient detail for planning purposes. Conclusions presented in this report attempt to identify the relative ranking of alternative solutions considered in the study.

It should also be noted that the study did not make any attempt to provide a complete evaluation of the various alternative solutions as impacts of economic, social, and environmental factors were not addressed. Such evaluations would be part of the necessary followup investigations.

III. ASSESSMENT OF WATER SUPPLY NEEDS

General

The Aquidneck Island communities are served for the most part by the City of Newport Department of Water which obtains its supply from a system of nine surface water reservoirs, seven of which are located on the Island and the two others in the neighboring communities of Tiverton, and Little Compton. Portsmouth is also served by the Portsmouth Water and Fire District system which purchases water from the Newport system and from the Stone Bridge Fire District System located in Tiverton.

Other communities considered in the development of water supply alternatives, namely, Barrington, Warren, and Bristol are all served by the Bristol County Water Company. This system obtains its supply from surface water reservoirs located in neighboring Swansea and Rehoboth, Massachusetts and from groundwater wells in Barrington.

Future water supply requirements were based upon population projections through the year 2020 and an allowance of per capita consumption.

Population

Estimates of the future population of the study area were obtained from Technical Paper Number 25 dated April 1975 prepared by the Rhode Island Statewide Planning Program. This report presents population projections for the State of Rhode Island and its thirty-nine cities and towns from 1970 to 2020 by five year intervals. Estimates of the effects of the U.S. naval base closings in 1973 are reflected in the population projections.

Results of population projections for the study area are shown in Table 1.

TABLE 1

POPULATION PROJECTIONS

Community	1970	1975	1980	1990	2000	2010	2020
Newport	34.6	30.0	31.0	33.0	34.0	36.0	38.5
Middletown	29.3	15.6	16.6	18.3	20.0	23.0	26.2
Portsmouth	12.5	13.0	13.7	15.0	16.3	17.7	19.4
Barrington	17.6	17.4	17.6	18.1	18.5	19.0	19.4
Warren	10.5	10.6	11.1	12.3	12.9	14.0	14.6
Bristol	17.9	18.7	19.7	21.6	22.1	22.5	22.9
Totals	122.4	105.3	109.7	118.3	123.8	132.2	141.0

Note: All figures are in thousands

It is understood that the state's population forecasts are currently being revised and may alter the figures presented above. However, inasmuch as the revised projections are not expected to be available for some time yet, the figures presented in Table 1 were considered the best available data and used to estimate future water supply needs in the study area.

Population Served

The population of the study area, similar to other parts of Rhode Island, relies heavily upon public water systems to furnish its water requirements. The measure of this reliance is demonstrated by noting that about 93 percent of the total Aquidneck Island population presently obtains water from public systems. In the entire study area, including Barrington, Warren, and Bristol, the percentage of total population that obtains water from public supplies is presently estimated to be about

92 percent. This degree of participation is in line with both the Rhode Island and New England averages of 93 and 88 percent respectively.

Estimates of the present population served by existing systems were obtained from records of the Rhode Island Water Resources Board. These data, together with analyses of the present degree of development, and the extent of the existing public water systems and future development potential, were utilized in estimating future population served.

Present Water Supply Systems

The City of Newport Department of Water, as mentioned earlier, obtains its supply from a system of nine surface reservoirs, seven of which are located on the Island and the remaining two on the eastern side of Narragansett Bay in Tiverton and Little Compton. The reservoirs on the island; namely, Easton Pond (north), Easton Pond (south), Nelson's Pond, Gardiner's Pond, St. Mary's Pond, Sisson's Pond, and Lawton Valley Reservoir have a combined useable storage of about 1.8 billion gallons and an estimated safe yield of about 4.9 mgd (million gallons per day). The two reservoirs on the mainland, Nonquit Pond and H. E. Watson Reservoir, account for approximately one half of the system's water supply having a combined useable storage of about 1.7 billion gallons and an estimated safe yield of about 4.6 mgd. The total combined safe yield of the Newport system is, therefore, about 9.5 mgd based upon most recent estimates. Nonquit Pond in Tiverton and Easton Pond (south) on the Island are reportedly subject to contamination as a result of salt water intrusion.

Water is pumped from the two mainland reservoirs to the Island system through a 20 inch main crossing under the Sakonnet River in the vicinity of High Hill Point in Tiverton. The pumping station has a capacity of approximately 5 mgd. A filtration plant, located at the Lawton Valley Reservoir, provides treatment for the two mainland reservoirs, St. Mary's Pond, Sisson's Pond, and Lawton Valley Reservoir and serves the demands of the northerly portion of the Newport system.

Water from Gardiner's Pond, Nelson's Pond, and both Easton ponds receives treatment in a filtration plant located near Easton Pond (north). Finished water is then transmitted to serve the demands of the southern portion of the Newport system.

The Portsmouth Water and Fire District system, as noted previously, obtains all of its water supplies from the Newport water system and the Stone Bridge Fire District system in north Tiverton. In turn, the Stone Bridge system receives its supply from Stafford Pond in Tiverton which has an estimated safe yield of 1.0 mgd.

Barrington, Warren, and Bristol are served by the Bristol County Water Company which receives its supply in part from surface water reservoirs located in Rehoboth and Swansea. These reservoirs have an estimated combined safe yield of about 2.5 mgd. Additional water supply is obtained from groundwater sources in Barrington which have an estimated safe yield of about 0.7 mgd. The total combined safe yield of the Bristol County Water Company system is, therefore, about 3.2 mgd.

Water Use in the Study Area

Water use in the Aquidneck Island communities from public systems increased from an average daily demand in 1968 of about 8.0 mgd to about 8.7 mgd in 1970. However, with the closing of the U.S. Naval installations on the Island in 1973, the current demand (1975) for water has dropped to about 7.2 mgd. During the period of large scale naval activity on the Island, about 40 percent of the Newport system demand was supplied to installations associated with the U.S. Naval bases. On the other hand, water supply for the upper Narragansett Bay communities of Barrington, Warren, and Bristol has remained fairly steady with an average daily demand of about 4.0 mgd reported in 1975.

Supply requirements can be basically associated with two general consumption categories -- municipal and industrial. Normally, municipal use includes all water supplied for domestic, commercial, and light industrial usage. All unaccounted for water is also generally included in the category of municipal water consumption. Industrial use depends upon the type and extent of industry and may vary widely between adjacent communities. Industrial consumption, however, tends to maintain a somewhat rough relationship to population change since such changes are frequently a measure of the change in industrial activity.

Since there are no major industrial establishments within the study area which require significant quantities of water for process or other uses, demands have been reduced to a per capita consumption rate. A review of consumption records for the water supply systems serving the study area shows that the per capita consumption in the Newport system is presently about 130 gallons per day. Similarly, the per capita water consumption in the Portsmouth Water and Fire District and Bristol County Water Company systems is presently about 75 and 80 gallons per day respectively.

Average daily consumption demands are, however, only part of the requirements to be met by a water system. Fluctuations in the monthly, daily, and even hourly demand for water must also be accomodated by a well-designed system.

Records for the Newport water system since 1968 show that consumption on the maximum day of the year has ranged from about 1.2 to 1.4 times the average daily requirement. Likewise, the average daily demand during the maximum month of the year has ranged from a low of about 1.1 to a high of about 1.2 times the average daily water consumption for the year. These ratios are somewhat lower than those normally associated with a municipal water supply system and are probably due, at least in part, to the system's limited capacity. It is reported that the capacity of the Newport system to meet maximum consumption requirements is limited to about 10 to 12 mgd, and historically the system's output has almost reached this capacity. For example, past records show that a maximum daily consumption rate of over 10.9 mgd and a monthly rate of over 9.6 mgd were experienced by the system during the summer of 1971.

An examination of the recent past pattern of water usage in the Newport system would seem to indicate that the ratio of maximum to average daily water consumption requirements will continue to increase into the future. For purposes of this study, allowances of 1.5 times and 2.0 times the average daily demand have been projected for the years 1990 and 2020 respectively.

Peak daily demands for the Bristol County Water Company system since 1970 have been about 1.4 times the average daily consumption for the year and have shown a general increase. Of particular interest in this system, is that records indicate the average daily consumption has exceeded the estimated safe dependable yield of the system in every year since the early 1960's. Reportedly, this system has had to impose constraints on water consumption during periods of maximum demand requirements. An allowance of twice the average daily water demand has been projected for this system for the years 1990 and 2020.

Projected Future Water Requirements

The population projections and future water requirements presented in this section are preliminary in nature. However, they are of sufficient accuracy to provide a reasonable comparison between available resources and future demands to afford an outline of potential deficits.

Estimated service population projections, as shown in Table 2, were developed from an analysis of existing systems and the potential for increased development within each community.

TABLE 2

SERVICE POPULATION PROJECTIONS

Community	1974	1990	2020
Newport	44, 300	33, 000	38, 500
Middletown	*	18, 300	26, 200
Portsmouth	10, 320	13, 500	19, 400
Barrington	42, 500	18, 100	19, 400
Warren	**	12, 300	14, 600
Bristol	**	21, 600	22, 900
Totals	97, 120	116, 800	141, 000

*Included in figure for Newport

**Included in figure for Barrington

Discussions with representatives of the Rhode Island Department of Economic Development and the Aquidneck Island Development Corporation regarding the disposition of lands and facilities formerly used by the U. S. Navy, indicate that no large scale industrial development is planned for the area. It is anticipated by the various economic development agencies and interests that the present plans for the former naval installations will not have any appreciable impact on the Island's future population or water supply requirements.

In view of the foregoing,consumption demand projections for the study area have focused on the expected increase in per capita water usage as the result of increased water supply, increased usage of modern household appliances, and corresponding increased standard of living.

However, it should be kept in mind that increased per capita consumption for future water demands will be offset, in some measure, by the public's awareness of water conservation practices. This latter consideration will tend to diminish historical per capita increases and result in a more realistic projection of future water demands.

From analysis of past consumption records within Rhode Island, projections for future per capita water demands were determined. The expected increase in per capita water consumption is dependent upon the availability of water within a given community and the adequacy of the present supply to meet future demands. For the Newport system, per capita consumption is expected to increase gradually from a present usage of about 130 gallons per day to 142 and 155 gallons per day in the years 1990 and 2020 respectively. The incremental increases between 1975 and 1990, and between 1990 and 2020, correspond closely with projections made in prior engineering studies for the area.

The other major water system in the study area, Bristol County Water Company is expected to experience per capita consumption increases from a present usage of about 80 gallons per day to 100 and 130 gallons per day in the years 1990 and 2020 respectively.

Total water supply requirements for each community in the study area were determined from per capita consumption projections and estimates of the population to be served by the years 1990 and 2020. Maximum daily consumption demands were also established based upon the criteria presented earlier in this section of the report.

Inasmuch as the study area communities are served by three distinct water systems, projections for future demands are presented in Table 3 by water system. In this way, the potential deficits of each system are more readily identified for further evaluation.

Adequacy of Existing Supplies to Meet Projected Demands

As noted previously in this section of the report, the consumption records for water systems serving the study area indicate that there is little margin for growth in some instances.

Future water demands developed for the Newport system indicate that even though future average daily consumption requirements can be met with existing supplies beyond 1995, the system, as it exists today,

TABLE 3

PROJECTED WATER DEMANDS
(million gallons per day)

System	1974 Avg.	1974 Max.	1990 Avg.	1990 Max.	2020 Avg.	2020 Max.
Newport Water Department	7.11	9.60	8.8	13.2	12.6	25.2
Bristol County Water Company	3.36	6.0[2]	5.2	10.4	7.4	14.8
Portsmouth Water and Fire District	0.77[1]	[3]	0.4[4]	0.8	0.4	0.8

(1) includes supply from Stone Bridge Fire District
(2) estimated
(3) data not available
(4) supplies obtained from Stone Bridge Fire District only

will be unable to provide service to meet maximum daily demands much beyond the middle to late 1980's. Much of this deficiency stems from the limited capacity of the present system to meet peak demands now and for the future.

The City of Newport is presently evaluating treatment facilities for its water supply system to increase the system's capacity to meet peak demands. A consultant's report on the expansion of the plant's capacity is expected in the near future. If the consultant's report recommends upgrading and/or expanding the treatment facility there, one reported constraint in the system's capability to meet peak demands may be removed. A second reported constraint is the capacity of the pipeline connecting the Island to Nonquit and Watson reservoirs. However, even if all constraints on the system's treatment and major transmission aqueducts were removed, the safe yield of the system would only be adequate until the mid 1990's.

Therefore, since the neasures to be proposed and their effect on the system's capacity to meet peak demands are unknown at this time, this study has sized all alternatives as additions to the existing facilities.

Similarly, the Bristol County Water Company has reported average daily consumptions which have exceeded the safe dependable yield of the system's capacity in recent years. In order to meet projected future consumption demands, the system would prove to be less than adequate.

A schedule of water supply deficits based on a comparison of reported existing system capacity and future demands expected to occur in the study area is shown in Table 4.

TABLE 4

WATER SUPPLY DEFICITS
(million gallons per day)

Year	Newport Dept. of Water		Bristol County Water Company		Portsmouth Water & Fire District	
	Avg.	Max.*	Avg.	Max.	Avg.	Max.
1990	+0.7**	2.2	2.0	4.7	***	***
2020	3.1	14.2	4.2	9.1	***	***

*assumes maximum capacity of Newport system is 11.0 mgd
**water supply surplus
***assumes that present Stone Bridge supply will be continued without change

Prior engineering studies have not identified any local water supply resources that could be used to augment existing supplies. Likewise, with the possible exception of the Newport system, there does not appear to be any reasonable margin for growth potential or for increasing the available capacity of the existing water supply systems. Additional water supply sources which can be used to meet average day requirements must of necessity come from off-island resources. Specifically, the resources to augment existing supply systems have been identified in areas on the western side of Narragansett Bay. The first of these is the proposed Big River Reservoir development located in the Pawtuxet River Basin and planned to provide additional water supply for the Providence metropolitan area. The second potential water resource alternative is the groundwater reservoirs located in the upper Pawcatuck River Basin in the Chipuxet and Usquepaug-Queens River watersheds. Another possible source of obtaining additional water supplies is, of course, in the use of desalination facilities which could be developed on the Island.

The following section of the report identifies alternatives for additional water supply for Aquidneck Island and presents an evaluation of their engineering effectiveness. Four overall alternatives are discussed. Two of these include the provision of additional source water from the proposed Big River Reservoir through pipeline routes shown on Plate 2. The third major alternative would draw water from groundwater reservoirs located in the upper Pawcatuck River Basin as shown on Plate 3. The last alternative would develop additional supply for the Island through a desalination Plant located on Aquidneck Island itself.

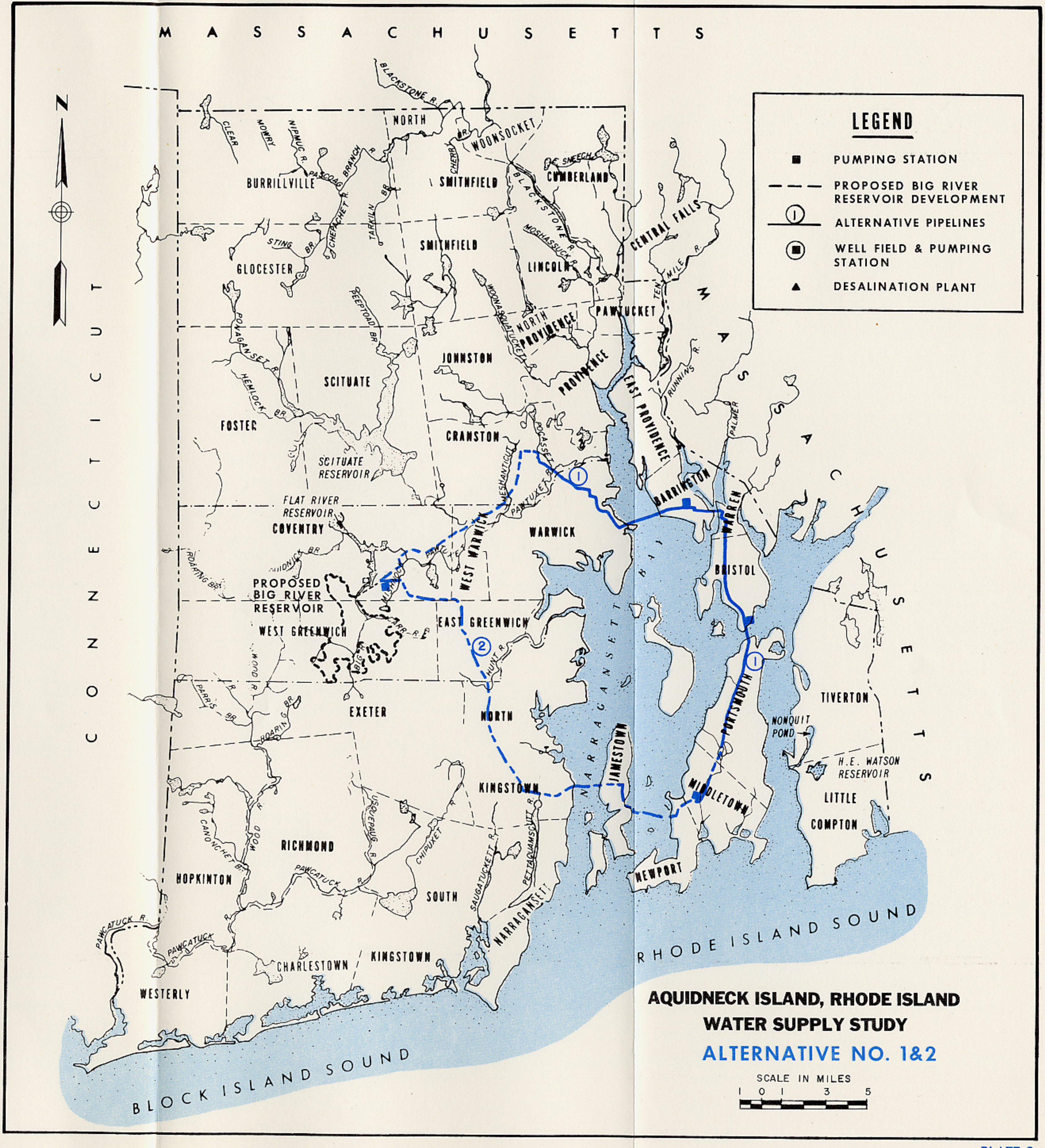
IV. FORMULATION AND ANALYSIS OF ENGINEERING ALTERNATIVES

General

Four basic alternatives were developed to provide additional water supply to meet the demands of the study area through 2020. The first of these considered a supply directly from the existing 102-inch aqueduct of the Providence Water Supply Board in the Cranston area with transmission facilities to serve several upper Narragansett Bay communities, as well as those on Aquidneck Island. The second alternative considered taking water supply directly from the proposed Big River Reservoir complex and conducting it to Aquidneck Island by way of Jamestown and crossings of Narragansett Bay. The third alternative for additional water supply considered development of groundwater resources in the upper Pawcatuck River Basin with transmission facilities to the Island similar to those proposed in Alternative No. 2. The fourth alternative investigated the viability of constructing desalination facilities on Aquidneck Island to augment existing supplies and to serve future needs.

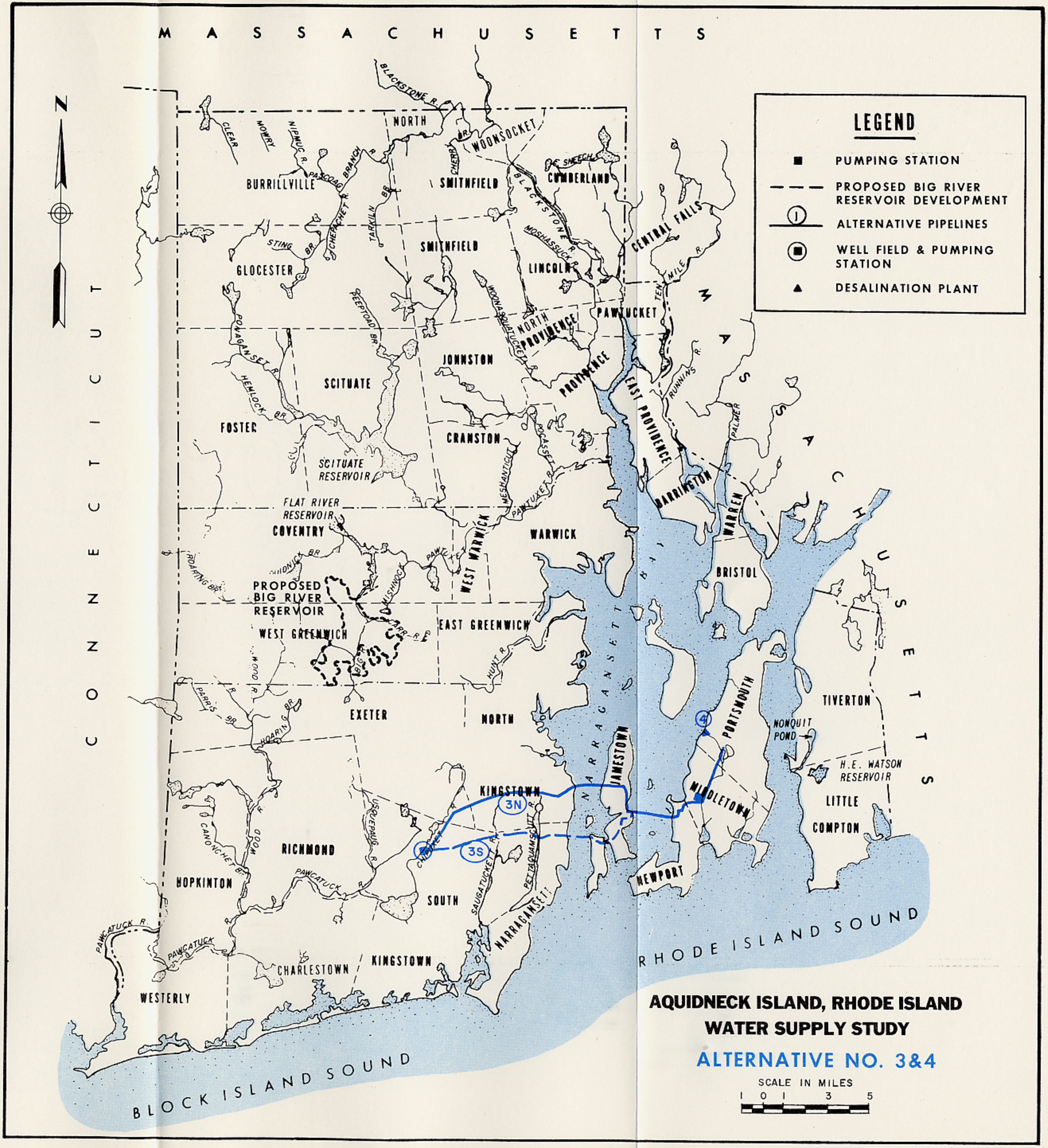
Methodology

All alternatives were formulated utilizing design criteria and guidelines that would provide a degree of uniformity for all solutions, as well as to allow an assessment of the economic feasibility of the various systems. These criteria and guidelines were chosen to be sufficiently generalized to permit their use in all alternatives developed, yet detailed enough to produce systems that were technically sound. Detailed investigations would be required for various components of each



AQUIDNECK ISLAND, RHODE ISLAND
WATER SUPPLY STUDY
ALTERNATIVE NO. 1&2

PLATE 2



AQUIDNECK ISLAND, RHODE ISLAND WATER SUPPLY STUDY

ALTERNATIVE NO. 3&4

PLATE 3

Planning Considerations

As a result of the uncertainty of proposed water supply projects included in the development of alternatives for this study and to accomodate certain basic considerations of existing supply system adequacy to handle future demands, some assumptions have been employed in the formulation of water supply plans for Aquidneck Island.

The following paragraphs describe the assumptions that have been utilized in developing the alternatives presented in this report:

1. The reported dependable safe yield of the Newport water system, consisting of entirely surface water supplies, is about 9.5 mgd. Normally such a system could be expected to handle flow variations of two to three times annual average daily demand requirements without adversely affecting the available storage of the system. However, the capacity of the Newport system to accomodate peak demands has been reported to be about 10 to 12 mgd. This limit on the system is reported to be caused by the inadequate capacity of pumping and transmission facilities to deliver water from the mainland reservoirs, which comprise about 50 percent of total system capacity, to the Island system; insufficient treatment capacity to meet extremes of consumption demands; and a generally insufficient system capacity to adequately accomodate even maximum day consumption requirements.

For purposes of this study, a maximum capacity of 11.0 mgd has been adopted for the Newport system in evaluating future maximum day water consumption requirements.

2. The Portsmouth Water and Fire District obtains part of its water supplies from the Stone Bridge Fire District system located in north Tiverton. Presently, this supply is estimated to be about 0.3-0.4 mgd with the remainder of Portsmouth's supplies being purchased from the Newport Department of Water. As the Stone Bridge supply is obtained from surface water sources, it has been assumed that a peaking factor of two could be reasonably applied to the average daily demands required by the Portsmouth system.

An average daily flow allowance of 0.4 mgd has been adopted for purposes of this study to be available for meeting the projected water supply demands of Portsmouth.

3. The existing 102-inch aqueduct of the Providence Water Supply Board terminates near Budlong Road in the City of Cranston. In the future, as the result of construction of

the proposed Big River Reservoir complex, this aqueduct will become part of the combined Scituate Reservoir-Big River Reservoir system that will serve the entire metropolitan Providence area. Hydraulics of the system at the connection of the 102-inch aqueduct as proposed in Alternative No. 1 following are presently unknown. However, for purposes of this study, it has been assumed that suitable pressures will be available to preclude construction of a booster pumping station in the vicinity of the connection to convey water to upper Narragansett Bay and Aquidneck Island communities.

4. Groundwater evaluation studies are presently being conducted by the Rhode Island Water Resources Board in cooperation with the USGS in the upper Pawcatuck River Basin. Inasmuch as this work has not yet been completed, the dependable safe yield of groundwater reservoirs in the area have not been fully established. Data reported in a prior study to determine groundwater availability in the upper Pawcatuck River Basin was utilized in the evaluation of such sources to augment supplies on Aquidneck Island.

For purposes of this study, it has been assumed that groundwater supplies in the upper Pawcatuck River Basin will be available in sufficient quantity to be considered in the development of water supply alternatives. Also, it has been assumed that the supplies available from groundwater resources will be of sufficient quality to preclude treatment, except for disinfection, in estimating the costs of water supply alternatives.

Description of Alternatives

Plans formulated to provide alternative sources of supplemental water supply to serve the future needs of Aquidneck Island are presented in the following paragraphs. Basically, four alternatives were developed in order to present comparison from an economic standpoint primarily. However, evaluation of the alternatives also provides information regarding the more salient advantages and disadvantages of each individual proposal thereby allowing a general ranking of the alternatives to be undertaken.

The proposed alternatives for off-island water supply were developed in accordance with the criteria presented earlier. The concept of constructing facilities for the conversion of sea water to potable water was developed from the information presented in Appendix A of this report. Cost estimates of the alternatives were derived utilizing the criteria presented in Appendixes A and B of this report.

It should be kept in mind that the alternative water supply plans presented in this report were developed utilizing some basic assumptions, changes in which could significantly alter the costs of the alternatives.

Alternative No. 1 In this alternative, additional water supplies would be obtained by connecting to the existing 102-inch Providence water system aqueduct near Budlong Road in Cranston. This system would provide an additional average daily flow of 7.3 mgd to supplement existing supplies of the Bristol County Water Company and the City of Newport Department of Water. Of this amount, 3.1 mgd would be required to augment supplies of the Newport system.

Water would be conveyed to existing transmission facilities of the Bristol County Water Company and the Newport Water Department by way of new transmission mains and two pumping stations as shown on Plate 2. The transmission facilities would consist of about 11.1 miles of 36 inch diameter main including a 1.1 mile subaqueous crossing of the Providence River between Conimicut Point in Warwick and Nyatt Point in Barrington; about 5.9 miles of 30 inch diameter main including a 0.1 mile subaqueous crossing of the Warren River; about 5.3 miles of 24 inch diameter main including a 0.5 mile subaqueous crossing of Mount Hope Bay in the vicinity of Mount Hope Bridge; and about 1.7 miles of 20 inch diameter main to a terminus in the Newport water system near Lawton Valley Reservoir.

Costs associated with construction of the proposed Big River Reservoir complex which could be assignable to Aquidneck Island communities under this alternative were prorated on the basis of future demand requirements. The initial yield of Big River Reservoir is estimated to be about 29.0 mgd while the average daily supplementary requirement for Aquidneck Island is 3.1 mgd. Applicable costs of the Big River Reservoir used in the economic analysis are, therefore, about 11 percent of the total.

The costs of facilities proposed under this Alternative No. 1 which serve not only the future requirements of Aquidneck Island communities but also the upper Narragansett Bay communities of Barrington, Warren, and Bristol were likewise prorated on the basis of flow. Supplemental maximum day demands of the Bristol County Water Company and Newport water system are estimated to be 9.1 mgd and 14.2 mgd respectively. The cost of joint facilities assignable to Aquidneck Island communities is, therefore, prorated at about 61 percent of the total cost of such facilities.

Estimated total project costs, average annual cost, and the unit cost of water supplied are shown in Table 5.

TABLE 5

ALTERNATIVE NO. 1 - BIG RIVER VIA BRISTOL COUNTY

COST ESTIMATES

Total Additional Supply	7.3 mgd

ESTIMATED PROJECT COST

Item	Estimated Cost
Transmission Facilities	$13,517,000
Pumping Stations	2,116,000
	$15,633,000
20% Contingencies	$ 3,127,000
	$18,760,000
23% Engr. & Design, Supv. & Admin.	$ 4,315,000
	$23,075,000
Prorated Cost of Transmission Facilities	$16,614,000
Prorated Cost of Big River Complex	8,703,000
Estimated Project Cost (Aquidneck Island)	$25,317,000

AVERAGE ANNUAL COST

Interest & Amortization 6 3/8% for 50 years	$ 1,882,000
Operation and Maintenance	221,000
Average Annual Cost	$ 2,103,000

COST OF WATER

Cost of water per thousand gallons $\frac{\$2,103,000}{1,131,500} = \$1.86$

Alternative No. 2 Additional water supplies under this alternative would be obtained directly from the proposed Big River Reservoir complex located in the Pawtuxet River Basin as shown on Plate 2. This system would provide an additional average daily flow of 3.1 mgd to augment existing supplies of the City of Newport Department of Water. Proposals for Big River call for construction of a reservoir having an initial yield of 29 mgd together with water treatment facilities and a transmission conduit to the West Warwick junction of the existing Scituate Reservoir aqueduct.

Water would be conveyed to existing transmission facilities of the Newport system by way of a new transmission main and two pumping stations. Transmission facilities would consist of about 29.2 miles of 30 inch diameter main running from Big River Reservoir through East Greenwich and North Kingstown to Route 138, then crossing the West Passage of Narragansett Bay to Jamestown and the East Passage of the Bay to a terminus in the Newport system near Lawton Valley Reservoir. About 3.2 miles of subaqueous crossings in the vicinity of Jamestown Bridge and the Newport Bridge are included in this alternative.

Costs associated with construction of the proposed Big River Reservoir complex which could be assignable to Aquidneck Island communities under this Alternative No. 2 were prorated on the basis of future demand requirements which was about 11 percent of the total Big River cost.

Estimated total project costs, average annual cost, and the unit cost of water supplied are shown in Table 6.

TABLE 6

ALTERNATIVE NO. 2 - BIG RIVER VIA JAMESTOWN

COST ESTIMATES

Additional Supply	3.1 mgd

ESTIMATED PROJECT COST

Item	Estimated Cost
Transmission Facilities	$19,090,000
Pumping Stations	1,454,000
	$20,544,000
20% Contingencies	$ 4,109,000
	$24,653,000
22.5% Engr & Design, Supv. & Admin.	$ 5,547,000
	$30,200,000
Prorated Cost of Big River Complex	$ 8,703,000
Estimated Project Cost	$38,903,000

AVERAGE ANNUAL COST

Interest & Amortization 6 3/8% for 50 years	$ 2,789,000
Operation and Maintenance	281,000
Average Annual Cost	$ 3,070,000

COST OF WATER

Cost of water per thousand gallons $\dfrac{\$3,070,000}{1,131,500} = \$2.71$

Alternative No. 3 Under this alternative, additional water supplies would be obtained from groundwater resources in the Chipuxet River watershed and Usquepaug-Queens River watershed located in the upper Pawcatuck River Basin as shown on Plate 3. This system would provide an additional average daily supply of 3.1 mgd to supplement existing supplies of the City of Newport Department of Water.

Two alternate routes were evaluated in this Alternative No. 3 for transmission mains to convey water from the proposed well fields. The first alignment, North Route, would follow, in part, the expected location of proposed Route I-895 to the vicinity of Jamestown Bridge. The remainder of the alignment would then be generally as proposed in Alternative No. 2; namely, crossings of Narragansett Bay to a terminus in the Newport system near Lawton Valley Reservoir. The second alignment, South Route, would follow Route 138 to the vicinity of Bridgetown in Narragansett, then cross Narragansett Bay to Jamestown. From this point, the alignment would be the same as for the North Route.

The description and cost estimates that follow are associated with the South Route only. Cost estimates associated with the North Route are not significantly different.

Water would be conveyed from groundwater wells in the upper Pawcatuck River Basin to existing transmission facilities of the Newport water system by way of a new transmission main and two pumping stations. Transmission facilities would consist of about 19.6 miles of 30 inch diameter main including about 3.0 miles of subaqueous crossings. The West Passage crossing of Narragansett Bay would be from South Ferry Road in Narragansett to Jamestown and the East Passage crossing in the vicinity of the Newport Bridge.

Well development facilities would include pumping stations and interconnecting transmission mains from the two reservoir areas. Treatment facilities would consist of equipment and structures for disinfection by chlorination.

Estimated total project costs, average annual cost, and the unit cost of water supplied are shown in Table 7.

TABLE 7

ALTERNATIVE NO. 3 - GROUNDWATER

COST ESTIMATES

Additional Supply	3.1 mgd

ESTIMATED PROJECT COST

Item	Estimated Cost
Transmission Facilities	$15,164,000
Pumping Stations	1,550,000
Groundwater Facilities	4,045,000
	$20,759,000
20% Contingencies	$ 4,152,000
	$24,911,000
23% Engr & Design, Supv. & Admin.	$ 5,730,000
Estimated Project Cost	$30,641,000

AVERAGE ANNUAL COST

Interest & Amortization 6 3/8% for 50 years	$ 2,046,000
Operation and Maintenance	348,000
Average Annual Cost	$ 2,394,000

COST OF WATER

Cost of water per thousand gallons $\frac{\$2,394,000}{1,131,500} = \$2.12$

Alternative No. 4   The feasibility of constructing desalination facilities on Aquidneck Island to augment existing supplies of the Newport system was developed and evaluated under this alternative. The proposed facilities would provide an additional average daily flow of 3. 1 mgd which was expected to satisfy the projected average demands of Aquidneck Island through the year 2020.

Facilities consisting of multi-stage flash distillation process equipment for conversion of sea water would be constructed at Carr Point in Middletown with the resultant potable water conveyed to existing transmission facilities of the Newport system near Lawton Valley Reservoir as shown on Plate 3 and Appendix A.

Costs associated with desalination facilities presented in this report were derived on the basis that the proposed facilities would produce power and thermal conversion from purchased fuel oils. Should some other source of energy be combined with the desalination facilities, certain modifications would be required. However, the net effect on capital costs from such an arrangement should be minor.

Operational costs and the unit cost of water, on the other hand, could be significantly influenced by change of energy source considerations. The unit cost of fuel reported in Appendix A makes up more than 40 percent of the estimated unit cost of water. Consequently any revision in the cost of fuel for operation could have a major effect on the overall cost of water produced. However, water produced from this alternative would still be the most expensive of the alternatives considered.

Estimated total project costs, average annual cost, and the unit cost of water supplied are shown in Table 8.

TABLE 8

ALTERNATIVE NO. 4 - DESALINATION

COST ESTIMATES

Additional Supply	3.1 mgd

ESTIMATED PROJECT COST

Item	Estimated Cost
Desalination Facilities	$24,800,000
22% Engr. & Design, Supv. & Admin.	5,456,000
Estimated Project Cost	$30,256,000

AVERAGE ANNUAL COST

Interest & Amortization 6 3/8 for 50 years	$ 2,020,000
Operation and Maintenance	4,252,000
Average Annual Cost	$ 6,272,000

COST OF WATER

Cost of water per thousand gallons $\dfrac{\$6,272,000}{1,131,500} = \$5.55$

Discussion of Alternatives

General As described in the preceding sections of this report, four basic water supply alternatives for the study area were developed and cost estimates prepared. Any one of these alternatives could provide the additional supply required to meet projected water demands of the Aquidneck Island communities through the year 2020.

The engineering effectiveness of the four alternative plans are discussed in the following paragraphs with a view towards allowing a general ranking of them to be undertaken. The basis of evaluating the individual alternatives is primarily one of economics. However, it is recognized that any follow-up studies to this feasability report would necessarily require consideration of technical, social, environmental, and aesthetic factors in the selection of a preferred plan.

Possible Solutions Additional off-island water supplies to supplement the existing systems serving Aquidneck Island were identified as being available from the proposed Big River Reservoir complex in the Pawtuxet River Basin and from groundwater resources in the upper Pawcatuck River Basin. Significant additional water resources on Aquidneck Island are non-existent. However, desalination processes for converting sea water into potable water were studied as a source of additional water supply and an alternative developed around this concept.

Alternative No. 1 - Under this plan, additional water supplies amounting to 7.3 mgd would be obtained from the Providence Water Supply Board's system, not only to serve the needs of Aquidneck Island, but also to serve demands of those communities presently served by the Bristol County Water Company. This estimated average day demand would represent about 7.5 percent of the Providence system's estimated 1990 safe yield.

a. Reliability - Transmission facilities would be constructed in existing public ways insofar as possible; however, two relatively major subaqueous crossings and one minor crossing amounting to about 1.7 miles of pipe ranging in size from 24 to 36 inches diameter would be included. The first major crossing would be constructed under the Providence River from Conimicut Point in Warwick to Nyatt Point in Barrington while the second major water crossing would be constructed under Mount Hope Bay in the vicinity of the Mount Hope Bridge. The third crossing would be constructed under the Warren River between Barrington and Warren. Treatment would be provided in existing facilities of the Providence Water Supply Board and facilities of the proposed Big River Reservoir complex.

b. Flexibility - Initial construction under this alternative would include transmission mains of the sizes proposed to preclude future pipeline construction to meet the area's needs. As noted before in this report, water mains have been selected with capacity sufficient to meet maximum day demands expected by the year 2020. Pumping stations would be constructed of sufficient capacity to handle flows expected through the year 2000 with provisions for the installation of additional units to meet projected maximum day requirements.

c. Timeliness - Preliminary engineering investigations relative to construction of the Big River Reservoir complex are presently being conducted. However, water supply under this alternative is obtained from existing facilities and could be implemented in anticipation of completion of the proposed Big River Reservoir facilities in the near future. Present average demands of the Bristol County Water Company, as well as projected mid 1980 maximum day requirements of the Newport water system, indicate that additional supplies will be required.

d. Equity - Additional water supply for the study area would be obtained from the Providence Water Supply Board which presently provides water through interbasin transfers to a number of out-of-basin communities. Part of the facilities under this Alternative No. 1 would also be constructed for the joint use of the recipient water systems; namely, Bristol County Water Company and City of Newport Department of Water. Cost-sharing arrangements for construction of these facilities would, therefore, be required for implementation of the alternative. The estimated cost of water supplied to Aquidneck Island communities under this Alternative No. 1 is $1.86 per thousand gallons.

Alternative No. 2 - Additional water supplies amounting to 3.1 mgd would be obtained from the Providence system under this alternative to serve the projected needs of Aquidneck Island. This estimated average day demand would represent only about 3.2 percent of the estimated safe yield of the Providence Water Supply Board system.

a. Reliability - Construction of transmission facilities to convey water to Aquidneck Island would be in existing public ways as much as possible. Subaqueous crossings of Narragansett Bay amounting to about 3.2 miles of 30 inch diameter pipeline would be included. The first major underwater crossing would be constructed under the West Passage of the Bay in the vicinity of the Jamestown Bridge. The second subaqueous crossing would be constructed under the East Passage of Narragansett Bay in the vicinity of the Newport Bridge. Water treatment would be provided in facilities proposed for Big River Reservoir complex.

b. Flexibility - As in Alternative No. 1, transmission mains sized to meet the long range needs of Aquidneck Island would be included in the initial construction. Pumping stations would be constructed to not only meet the short range needs of the Island, but also to allow expansion of facilities to handle the projected maximum day consumption requirements.

c. Timeliness - Additional supplies under this Alternative No. 2 are contingent upon construction of the proposed Big River Reservoir complex. Study area needs for future additional water supplies would be obtained directly from the Big River facilities. Consequently, in order to meet the short range deficits projected for the Newport water system, construction of the Big River reservoir complex would have to be undertaken prior to implementation of this Alternative No. 2.

d. Equity - Out-of-basin transfer of water would be required to provide additional supplies for Aquidneck Island. Unlike Alternative No. 1, the water supply needs of the upper Narragansett Bay communities of Barrington, Warren, and Bristol would not be relieved. Construction of separate facilities to serve such needs in conjunction with the facilities proposed under this plan would not appear to be economically efficient. The estimated cost of water supplied to Aquidneck Island under this Alternative No. 2 is $2.71 per thousand gallons.

Alternative No. 3 - Supplies amounting to 3.1 mgd to supplement the existing system serving Aquidneck Island would be obtained from groundwater aquifers in the upper Pawcatuck River Basin. Conveyance to the Island would be through transmission facilities connecting to the existing transmission system of the Newport Water Department.

a. Reliability - Transmission facilities would be constructed in public rights-of-way wherever possible. However, the North Route shown on Plate 3 was expected to follow the alignment of proposed Route I-895 and be constructed concurrently with the highway. Subaqueous crossings of Narragansett Bay are included in this plan and would consist of about 3.0 miles of 30 inch diameter pipe. The West Passage crossing included in the North Route would be constructed as in Alternative No. 2 in the vicinity of Jamestown Bridge. Facilities included in the South Route would require construction of an underwater pipeline running from South Ferry Road in Narragansett to Jamestown. The subaqueous crossing of the East Passage of Narragansett Bay would be the same as in Alternative No. 2. Treatment facilities, consisting of disinfection by chlorination, would be provided in the facilities for groundwater development.

b. Flexibility - Transmission mains of the sizes proposed under this plan would be included in the initial construction to preclude additional pipeline construction to meet future water supply demands. Pumping facilities would include provisions for expansion to meet the maximum day requirements projected for Aquidneck Island. Likewise, groundwater development facilities would include provisions to allow expansion beyond the short-range requirements.

c. Timeliness - Additional supplies of water to serve Aquidneck Island communities under this plan would be predicated on the development and construction of groundwater facilities in the upper Pawcatuck River Basin. In order to meet the mid-1980's devidit projected for the Newport system, water supplies from groundwater resources in the Chipuxet River watershed in conjunction with those in the Usquepaug-Queens River watershed would have to be constructed prior to implementation of this Alternative No. 3.

d. Equity - Most, if not all, the developable groundwater in the Upper Pawcatuck River Basin would be transferred out of basin to supplement the projected needs of Aquidneck Island. Future water consumption requirements indicate that additional supplies providing about 14. 2 mgd would be needed to meet projected 2020 maximum day demands. The estimated cost of water supplied as proposed in the South Route under this Alternative No. 3 is $2. 12. The costs associated with the North Route are not significantly different.

Alternative No. 4 - Desalination facilities were investigated as an additional source of water supply to serve the future needs of Aquidneck Island. For purposes of this study, desalting techniques were evaluated to determine their applicability as a supplemental source of water supply to meet future demands of the Island communities. Considerations for desalination techniques were made to preclude the use of off-island supplies to meet future needs, as well as to evaluate such use for delaying the construction of pipelines crossing Narragansett Bay. As a result of these investigations, this Alternative No. 4 was developed around desalting facilities that would provide additional water supplies amounting to 3. 1 mgd which would be conveyed to the existing Newport system.

a. Reliability - Multi-stage flash distillation processes for conversion of sea water into potable water is by far the most widely used of all desalting technologies. Plants incorporating this process are, and have been, the overwhelming choice for large scale facilities supplying nearly 70 percent of the over 500 mgd of plant capacity on order or already installed. Familiarity of operation of such facilities is, therefore, well understood.

b. Flexibility - Desalination facilities, being modular in design could be constructed in phases to provide sufficient additional supply to meet the Island's needs. However, as noted later in this section, the facilities would have very limited capability in meeting the projected water supply needs of Aquidneck Island communities.

c. Timeliness - Desalination facilities would provide additional water supplies to meet average day demands of the Newport system through the year 2020. The design capacity of these facilities, 3. 1 mgd, would not be sufficient, however, to provide additional supplies for meeting projected maximum day demands of the Island. Average day demand projections indicate that additional supplies would not be required until the late 1990's, however, projections for maximum day demands indicate that such supplies would be needed by the middle 1980's. Even if desalination facilities were constructed at this time, the 3. 1 mgd additional capacity would only be sufficient to take care of demands through about 1990.

d. Equity - Desalination facilities for additional water supply would be an ideal situation in regard to Aquidneck Island as they would preclude the use of water from other areas to meet future needs. However, such facilities are quite expensive to construct, and, in these days of skyrocketing energy prices, are even relatively more expensive to operate. The estimated cost of water supplied under this Alternative No. 4 is $5.55 per thousand gallons.

V. CONCLUSIONS

This study of the long-range water supply needs of the Aquidneck Island area has resulted in the following principal conclusions:

1. To insure adequate water supplies to serve projected growth and development of the study area, additional water supply sources must be developed.

2. No appreciable quantities of additional groundwater or surface water are available for development on Aquidneck Island.

3. Supplemental water supplies, of the quantity required to meet the projected maximum demands of the study area, must, of necessity, be obtained from off-island resources.

4. Population growth in the study area is projected to increase from about 105,000 people in 1975 to approximately 118,000 in 1990, and 141,000 by the year 2020. Approximately 99 percent of the estimated 1990 population is expected to be served by municipal water systems; while by 2020 the entire estimated population is expected to be served.

5. Average water demands for the study are estimated to increase from a 1974 level of about 11.2 mgd to 14.4 mgd in 1990, and 20.4 mgd by the year 2020.

6. There are presently three water supply systems serving study area communities with the two major systems accounting for approximately 93 percent of the total water supplied.

7. Viewing the existing water resources of the study area as a whole, surface water and groundwater supplies are available in sufficient volumes to meet only average day water demands through the late 1990's. However, due to inadequacies in individual systems, additional supplies are needed now to adequately meet present demands.

8. Major facilities necessary to develop supplemental water resources are required if study area communities are to be assured adequate water supply for the future.

9. Out-of-basin transfers of water are a necessity if projected water requirements of the study area are to be met. This transfer requirement is not occasioned by a question of "least costly alternative," but rather by the fact that there are simply not enough available resources within the study area to meet the demands projected for the future.

10. Alternative plans for additional water supply reported in this study are not purported to be the only such way of serving study area communities; rather, the alternatives were formulated to provide a means of identifying different solutions for meeting future water supply needs of Aquidneck Island and to allow their comparison on a common basis.

11. The following table presents the costs associated with the four alternatives developed in the study. The costs shown are assignable to Aquidneck Island for easier comparison.

	Estimated Project Cost	Average Annual Cost	Cost of Water Per 1,000 Gallons
Alternative No. 1	$25,317,000	$2,103,000	$1.86
Alternative No. 2	38,903,000	3,070,000	2.71
Alternative No. 3	30,641,000	2,394,000	2.12
Alternative No. 4	30,256,000	6,272,000	5.55

12. Some of the more important features of the various alternative plans are presented in the following tabulation:

	Advantages	Disadvantages
Alternative No. 1	Barrington, Warren, and Bristol water needs accomodated. (Plan could be implemented in anticipation of Big River Reservoir facilities.) Least costly alternative for production of water to supply Aquidneck Island. Augments supply for all projected water demands, both average and maximum.	Requires interbasin transfer of water from Providence system. Requires construction of subaqueous crossings of Providence River and Mount Hope Bay. Requires new institutional and financial arrangements for implementation.
Alternative No. 2	Augments supply for all projected water demands, both average and maximum.	Requires interbasin transfer of water from Big River Reservoir system. Requires construction of major subaqueous crossings of Narragansett Bay. Second most costly alternative for production of water to supply Aquidneck Island. Requires construction of Big River Reservoir complex prior to implementation Requires new institutional arrangements for implementation.

	Advantages	Disadvantages
Alternative No. 3	Augments supply for all projected water demands, both average and maximum. Second least costly alternative for production of water to supply Aquidneck Island	Requires interbasin transfer of water from upper Pawcatuck River Basin. Requires construction of major subaqueous crossings of Narragansett Bay Requires construction of groundwater development facilities prior to implementation. May have adverse impact on low stream flows. May require higher degree of treatment in time. Requires new institutional and financial arrangements for implementation.
Alternative No. 4	Does not require interbasin transfer of water.	Most costly alternative for production of water to supply Aquidneck Island Does not provide supplemental supply to meet all projected water demands. High capital and operational costs not decreased by increased plant capacity.

APPENDIX A

DESALINATION FACILITIES

Cost estimates presented in this Appendix A were utilized in preparing the various cost estimates associated with Alternative No. 4 in the report. It should be noted that the costs presented in the report include allowances for Engineering and Design, and Supervision and Administration and, therefore, differ from the construction costs shown herein.

ENGINEERING REPORT

ON

DESALINATION OF WATER

FOR

AQUIDNECK ISLAND, RHODE ISLAND

PREPARED FOR

NEW ENGLAND DIVISION
CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

HH&B Hayden, Harding & Buchanan, Inc.
Consulting Engineers

MAY 1976

Hayden, Harding & Buchanan Inc. Consulting Engineers

June 29, 1976

Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Re: Contract No. DACW33-76-17-0833
Our Ref. No. 76-114

Gentlemen:

In accordance with the terms and conditions of the referenced contract, we have conducted an engineering study of desalination practices as they might apply to providing an auxiliary supply of potable water to Aquidneck Island, Rhode Island. The technical report is contained herein and transmitted herewith.

Our study was broken down into several steps. These were:

1. A literature review regarding desalination processes to determine the applicability of each process to the requirements at Aquidneck Island.
2. Selection of one process as being most appropriate for use in supplementing the Island's water requirements.
3. Selection of a potential site for the desalination facility considering the proximity to the source of water for treatment and the ability to deliver the treated water to the Island's existing transmission facilities.
4. Development of capital and operating costs for the selection process for capabilities ranging from 1 to 10 million gallons per day (gpd).

1340 Soldiers Field Road, Boston, Massachusetts 02135 617/254-6930

5. Preparation of a report discussing the findings of our study.

SUMMARY

This study reviewed the various methods of providing an auxiliary water supply for Aquidneck Island through desalinization of saline water surrounding the Island. Of the technologies available, the multistage flash distillation process (MSF) is by far the most often used method for conversion of sea water. Based on the historical reliability and general familiarity with MSF, we have recommended that this be the process considered for use.

Further investigation indicated that the attendant costs of an MSF plant would be an installation cost on the order of $8.00 per gallon per day of production capacity with operating and maintenance costs on the order of $3.10 per thousand gallons (Kgal) and an annual replacement factor of three percent of initial investment. Based on a one million gallon per day facility, the projected unit cost of water is $5.94 per Kgal.

HISTORY

Until the early 1950's, desalination of water was generally confined to small installations serving military and civilian populations in locations having no other source of potable water. Emphasis in design was usually concerned with the physical size of the desalination units for shipboard installations and for transportation of land based facilities.

In the early 1950's, the sheikdom of Kuwait initiated the installation of large, landbased seawater desalting facilities. During the Eisenhower Administration the Office of Saline Water (now part of the Office of Water Research and Technology) was organized within the Interior Department.

The thrust during the 1950's and early 1960's was in research to find technologies whereby saline water conversion could be accomplished. As theories were advanced process development and marketing followed closely. Due to the pressure of competition between suppliers, quality of equipment diminished, often with less than favorable results. Despite the disenchantment thus engendered, considerable advancements in designs and technologies were made.

The late 1960's saw a shift in emphasis from research and presentation of theory to development and refinement of process technologies. This shift in emphasis was reflected in the increase in desalting capacity from 29 million gallons (U.S.) per day (mgd) in 1959 to 178 mgd installed or under construction by 1969. By the end of 1974, another 349 mgd had been installed or was under construction.

Since 1974, the increased cost of energy has caused potential users to restudy the economies of employing desalination processes, with an associated slowing down of the rate of construction of new facilities.

AVAILABLE TECHNOLOGIES

At the present time there are commercially available two basic methods of desalination. These are: membrane processes and distillation processes.

Also available commercially are ion exchange and freezing processes. These, however, are usually used for special applications and relatively small capacities. Ion exchange is normally used on waters having less than 2000 ppm (parts per million) total dissolved solids content (TDS). Installed capacities have been on the order of 10 mgd. Freezing process equipment is available in capacities on the order of 100,000 gallons per day (gpd) and can be applied to high solids content water (50,000 ppm).

The various processes are shown schematically in Appendix I. Figure I-1 presents a generalized flow pattern for a desalination facility. All the usual ancillary handling and conditioning facilities are shown. Figures I-2 and I-3 show the primary distillation processes in use today, multiple stage flash distillation (MSF) and vertical tube evaporator (VTE) processes.

Hybridized plants combining various basic processes and energy input methods are shown in Figures I-4 and I-5.

The membrane processes, electrodialysis (Figure I-6) and reverse osmosis (Figure I-7), schematics show the flow patterns of the product water and concentrated waste brines.

Figure I-8 shows the treatment pattern for the vacuum freezing process using vapor compression as an energy transfer method.

Two step ion exchange to remove both cations and anions is shown on Figure I-9.

It is not the intent of this Report to present a complete discussion of the technologies involved in each of the above mentioned processes. Each process has been the subject of considerable research. Development of the process technologies has progressed to the point where commercial units of each process are available from manufacturers.

PROCESS SELECTION

Through the information gathered during review of available literature, and through discussions with manufacturers' personnel and OSW it was found that distillation processes are the most reliable for converting sea water having a TDS content on the order of 35,000 ppm. Freezing processes are also applicable to sea water conversion but product water has a higher total dissolved solids content than distillation process effluents and commercially available plant size is limited.

Membrane processes (electrodialysis and reverse osmosis) and ion exchange processes are more economically used on brackish water having a lower TDS content than on sea water. Research is being conducted on utilizing reverse osmosis as a method for converting seawater. As of this writing available information indicates that the process is not yet viable for application at Aquidneck Island.

Of the several types of distillation processing equipment now being manufactured, multistage flash distillation (MSF) seawater plants are and have been the overwhelming choice for large scale facilities, supplying nearly 70% of the over 500 mgd of plant capacity on order or installed. The investigation brought out that except for research, the major funding (U.S., Saudi Arabia, etc.) of desalination processes for seawater conversion is for the MSF process. Therefore, because of the benefits derived through familiarity and applications testing from the many existing installations, the multistage flash distillation process was selected as the most appropriate desalination method for serving Aquidneck Island.

SITE LOCATION

To make the selection of a site for the proposed facility, U.S. Coast and Geodetic Survey data on tidal currents and topographic maps, data on the existing water system and projected requirements which were obtained from the Corps of Engineers and other data on Aquidneck Island available from previous studies made in house were reviewed. From these data, the site recommended for consideration is Carr Point. This site is shown on Figure 1.

The most important criteria influencing this decision were:

1. Availability of land in close proximity to deep water.
2. Availability of highway and rail access.
3. Proximity to existing water treatment facilities and transmission network.
4. Central location of the Island.

These factors should act to reduce the capital and operating costs associated with the proposed desalination facility.

Other sites were considered but were eliminated by failure to meet the above criteria as adequately as does Carr Point. Some of the sites considered were: Breton Point, Castle Hill, Coddington Point, Sachuest Point, Sandy Point Coggeshall Point, and Arnold Point.

CAPITAL INVESTMENT COST

From discussions with manufacturers and from recent proposals for desalination facilities, it has become apparent that capital investment costs are dependent upon two factors. These are the size of the proposed facility and the quality of the equipment proposed to be installed.

Working on a unit cost basis in dollars of capital investment per gallon of plant capacity, available information indicates that the traditionally anticipated economies of scale (the "bigger-is-cheaper" effect) is minimal. The data on plant costs indicate that the economies generated by increased plant size are less than the statistical error of the estimate of cost.

Investigations into the reasons for such an effect showed that, the largest plant size reported was 8 mgd. Larger capacity plants are made up of smaller modules. The Saudi Arabian desalination program, for instance, reportedly uses 6 mgd (5 mgd Imperial) modules.

Further reasoning shows that heat transfer per unit area of contact surface is relatively fixed and the thermal energy required for phase change is fixed. Other design criteria such as number of stages, stage volume and pipe capacity all have relatively inflexible cost-capacity ratios.

The construction cost of a multistage flash distillation facility, located at Carr Point, Aquidneck Island, Rhode Island is estimated to be on the order of $8.00 per gallon of daily production capacity. This figure is broken down as follows:

ITEM	UNIT COST - $/gpd
Intake	$0.75
Pretreatment	0.50
Brine Disposal	0.50
Site Development	.25
Process Equipment	5.20
Other costs (Post Treatment, On-Site Storage, etc.)	0.80
TOTAL	$8.00/gallon per day

In order to reduce the capital investment cost significantly it will be necessary to revise the scope of the project. By eliminating some functions, such as pretreatment, and radically reducing the quality of installed equipment, the capital investment cost might be reduced to as little as $3 per gallon of capacity.

The effect of such a move would be increased operation and maintenance costs, reduced expected life of the facility and diminished product water quality. Such revisions have, in the past, resulted in increased unit cost of water.

OPERATING COSTS

Unit operating costs, as with capital investment, are reportedly independent of plant capacity. Only labor costs show any effect of economy of scale and even here the variation with scale is again within the statistical variation of the estimate. Information provided by manufacturers for facilities of recent origins, indicate an operational cost of $3.10 per thousand gallons(Kgal). This figure is derived as follows:

Energy: (for all power) - $1.04 per Kgal per $1 per million Btu energy cost. Based on $14.50* per barrel cost of heating oil having a thermal content of 5.95 million Btu per barrel results in an energy cost of $2.44 per Kgal.

Chemicals: (Pre and Post Treatment) $0.10 per Kgal.

Operations:	Labor	$0.43
	Supplies, Tools, etc.	0.15
	TOTAL	$0.58 per Kgal.

*Bulk rate to end user estimated by Atlantic-Richfield Oil Co. Providence, R.I.

ANNUAL OPERATIONS COST - SUMMARY

ITEM	UNITS COST $/Kgal
Fuel	$2.44
Chemicals	0.10
O & M	0.58
TOTAL	$3.12 use - $3.10 Kgal

Annual maintenance and periodic major parts replacement, over and above normal operating expenses, have been reported to be three percent of initial investment for facilities similar to those recommended herein. This allowance will provide a sinking fund to provide replacement motors, pumps, pipes, major overhauling and like activities.

TOTAL ANNUAL COST

Since unit costs for desalination of water are virtually unaffected by plant capacity, annual costs for a 1-mgd (million gallons per day) facility were developed by borrowing money of 6 1/8 percent and assuming a plant utilization or on-line factor of 80%. The projected useful life of the project was taken as 30 years, resulting in an annual amortization factor of 0.0736. Replacement of parts through the annual maintenance program should extend the life of the project beyond that time.

The following data evolve:

Total Capital Investment 1,000,000 gpd x $8/gpd = $8,000,000

Average Annual Production 365 days x 1 mgd x 0.80 = 292,000,000 gal./year

Annual Costs:

Capital	$8,000,000 x 0.0736	=	$588,800
Operation	292,000,000 x $\frac{\$3.10}{1000}$	=	905,200
Maintenance	$9,000,000 x 0.03	=	240,000
TOTAL ANNUAL COST		=	$1,734,000

Average Water Cost = $1,734,000/292,000 = $5.94/Kgal

ALTERNATIVES

The estimates of cost presented herein were derived on the basis that the proposed facility would produce its own power and thermal conversion from purchased fuel oils. In the event that a power generating station or other source of energy were to be combined with the desalination facility certain modifications would be necessary.

The capital cost of energy conversion using energy from another source would need to be compared to the cost presented herein. The net effect on the estimated capital cost should be minor.

The cost of fuel at $2.44 per Kgal makes up more than 40% of the estimated unit cost of water at $5.94/Kgal. Any revision in the cost of operation for fuel, however, would have major consequences.

It is beyond the scope of this report to speculate on the possibility of energy availability or on its probable costs.

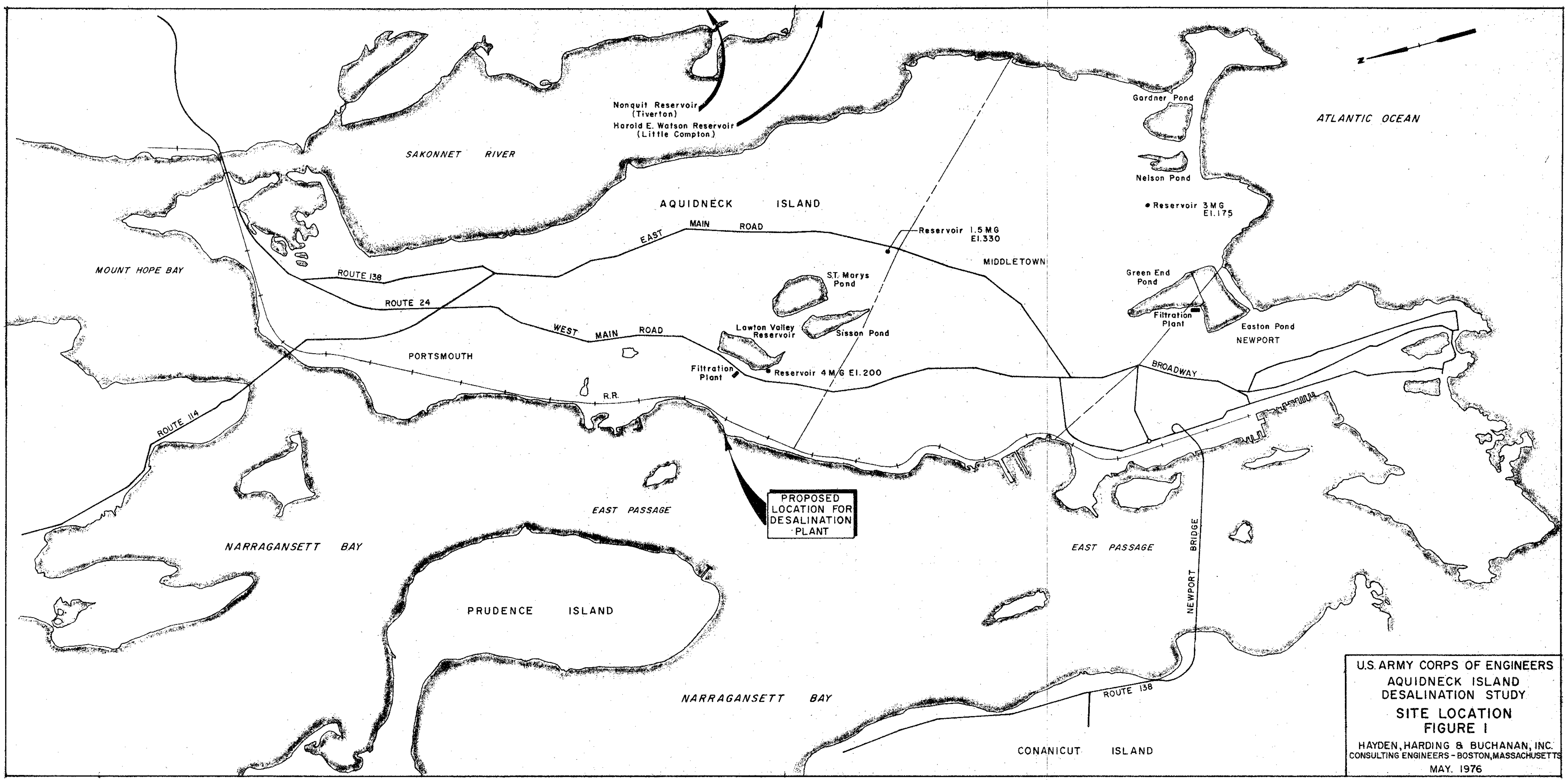
We are pleased to have been able to be of service to the Corps of Engineers on this project and are available, at your convenience, for any further questions or discussions.

Very truly yours,

HAYDEN, HARDING & BUCHANAN, INC.

By

John L. Hayden
President



U.S. ARMY CORPS OF ENGINEERS
AQUIDNECK ISLAND
DESALINATION STUDY
SITE LOCATION
FIGURE 1
HAYDEN, HARDING & BUCHANAN, INC.
CONSULTING ENGINEERS - BOSTON, MASSACHUSETTS
MAY, 1976

LIST OF REFERENCES

American Water Works Association, Inc., Water Quality and Treatment, Third Ed., McGraw-Hill Book Co., New York, 1971.

Rich, L.G., Unit Operations of Sanitary Engineering, John Wiley & Sons, Inc., New York 1961.

Rich, L.G., Unit Processes of Sanitary Engineering, John Wiley & Sons, Inc., New York, 1963

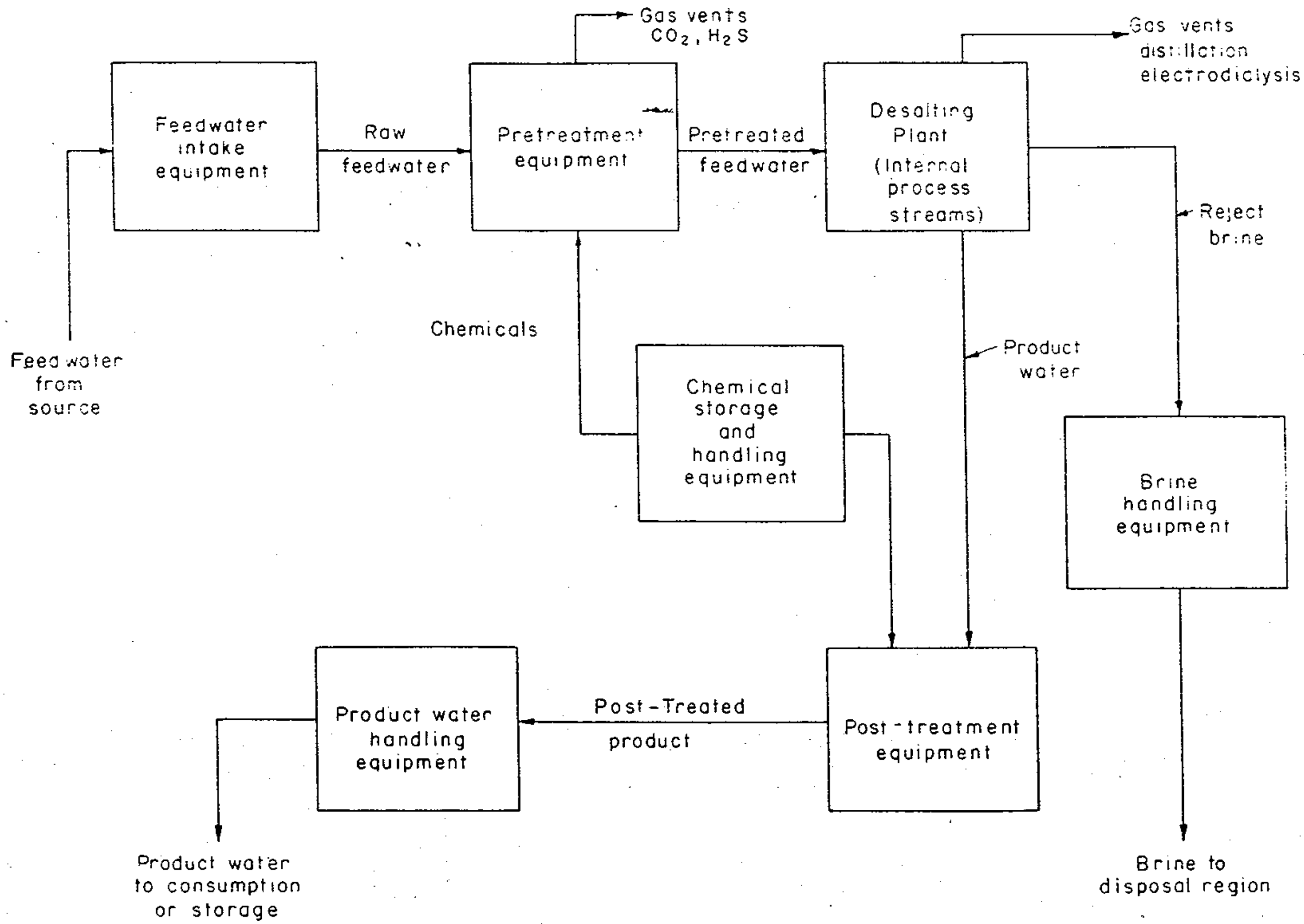
U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Tidal Current Charts, Narragansett Bay, Rockville, Maryland, 1971

U.S. Department of the Interior, Office of Saline Water and Bureau of Reclamation, Desalting Handbook for Planners, Washington, D.C., 1972

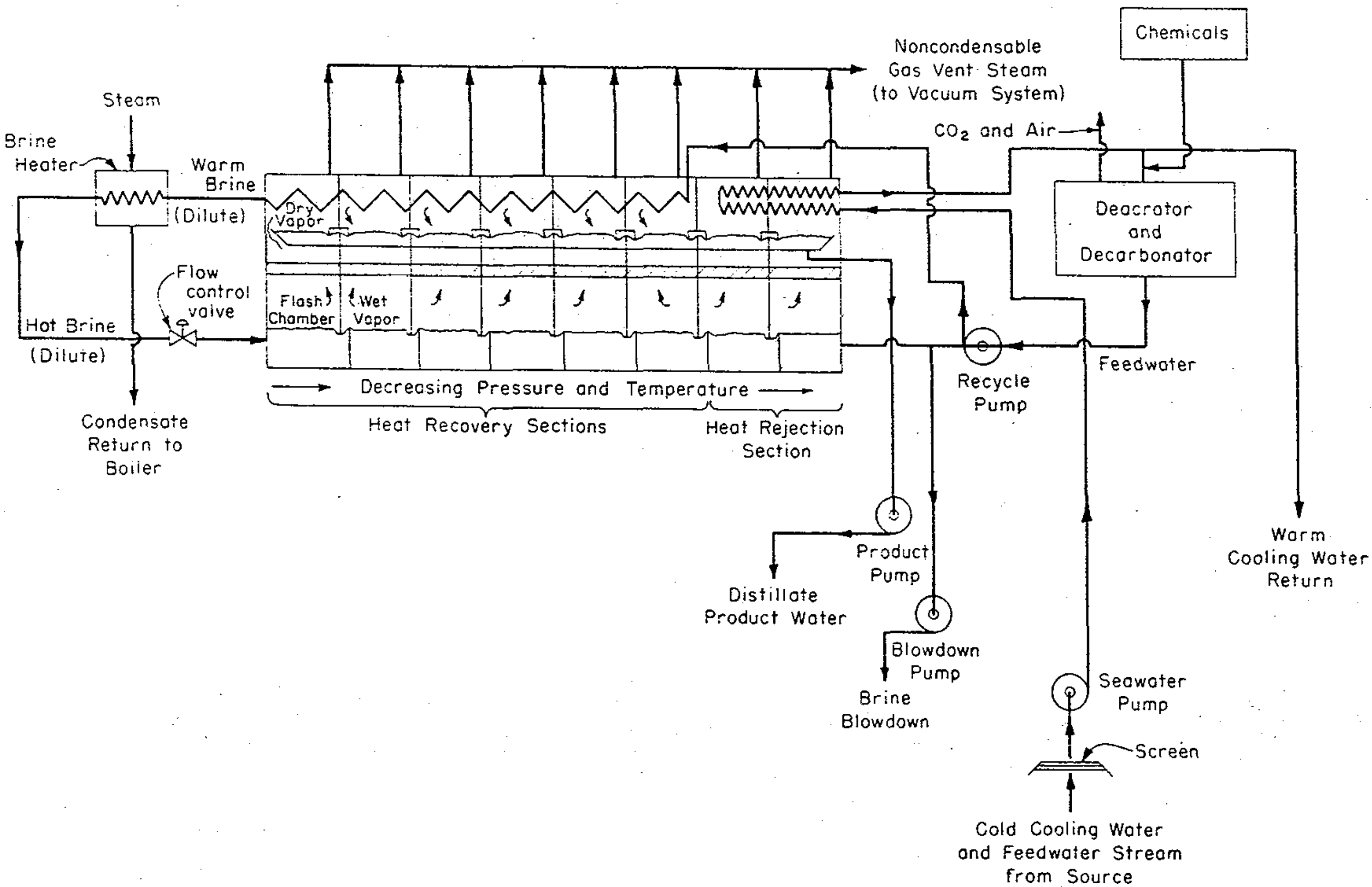
Note: Addenda were reproduced as deemed appropriate from the above sources.

ADDENDUM

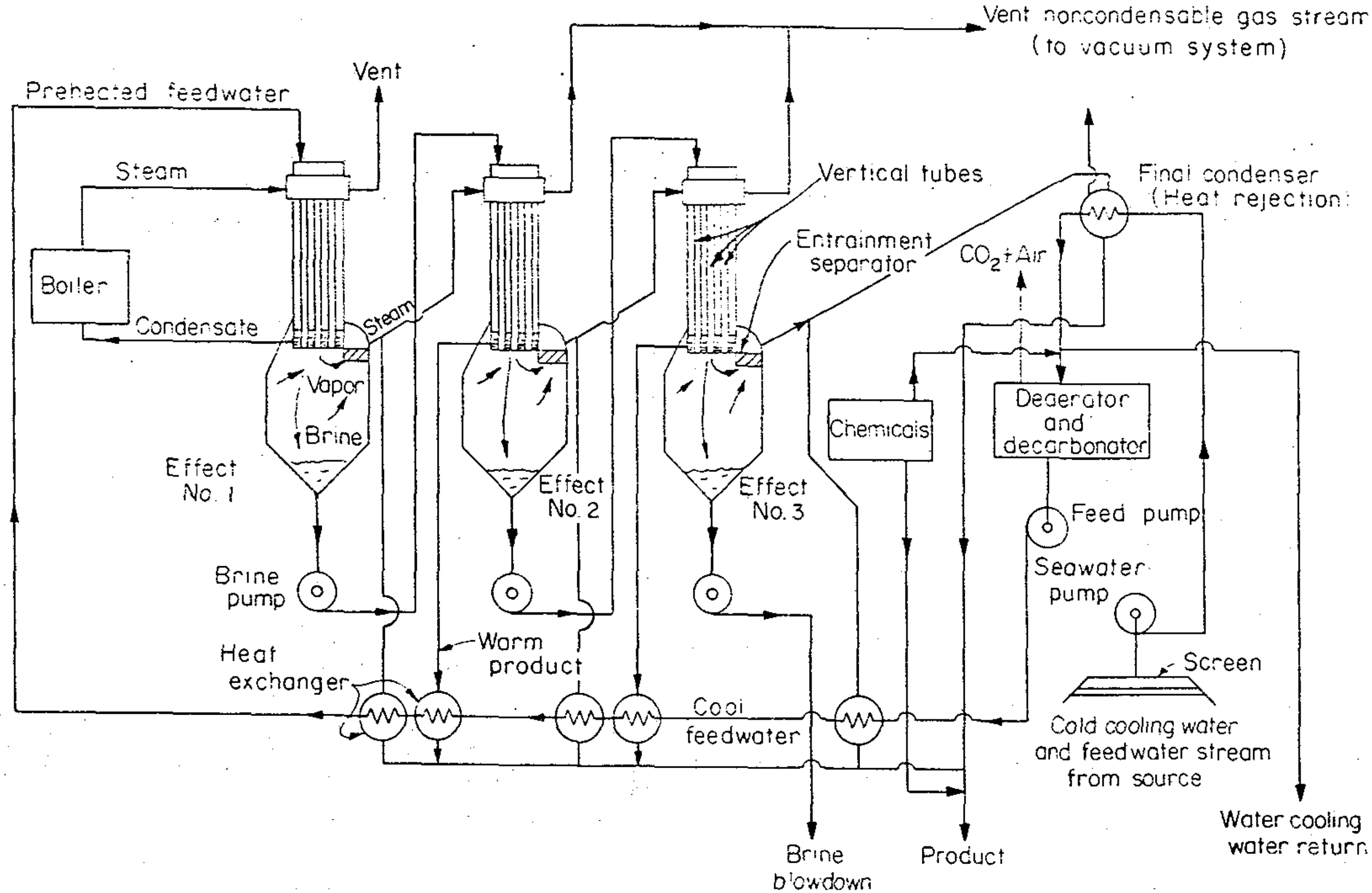
DESALINATION PROCESSES



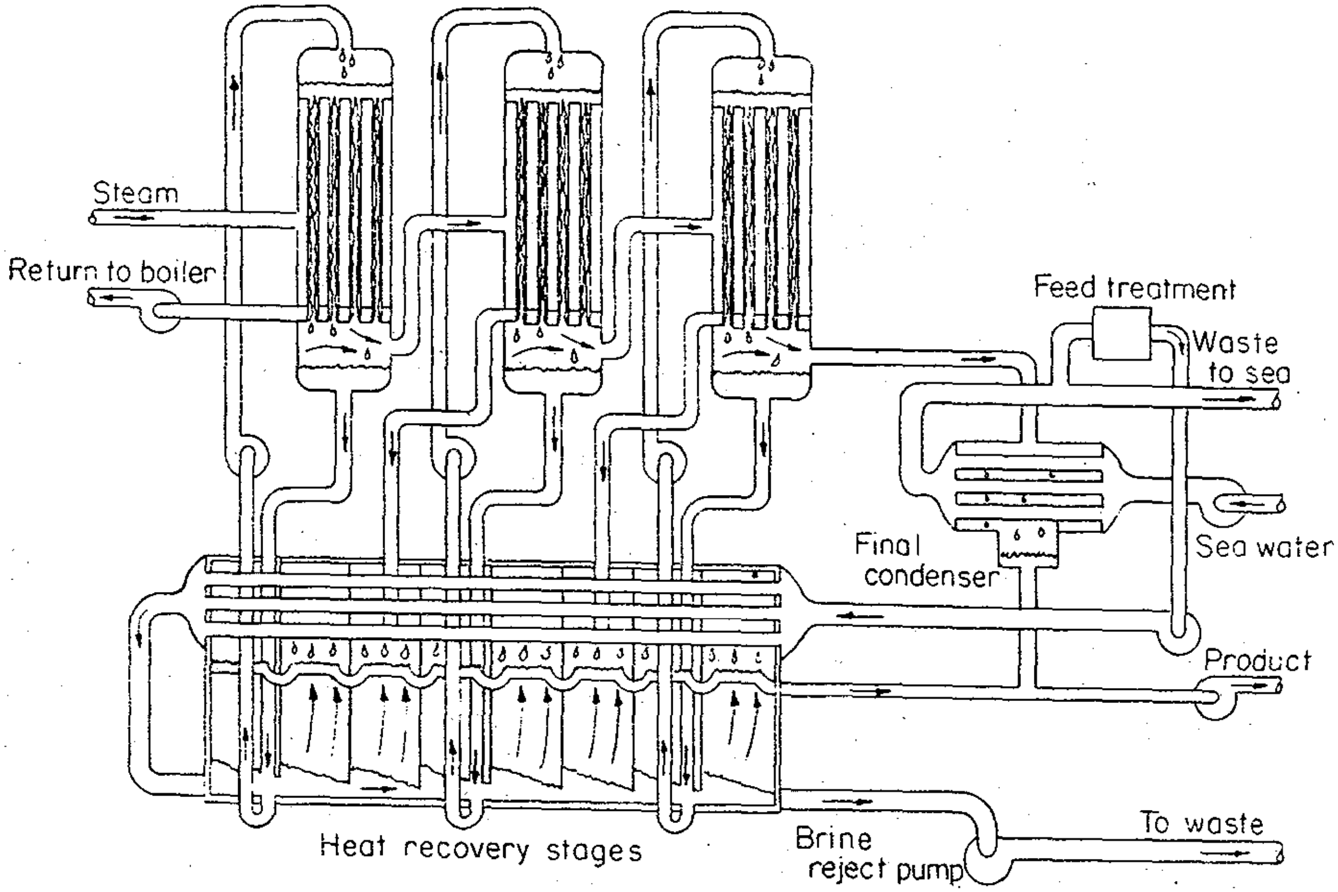
GENERAL DESALTING PLANT SCHEMATIC



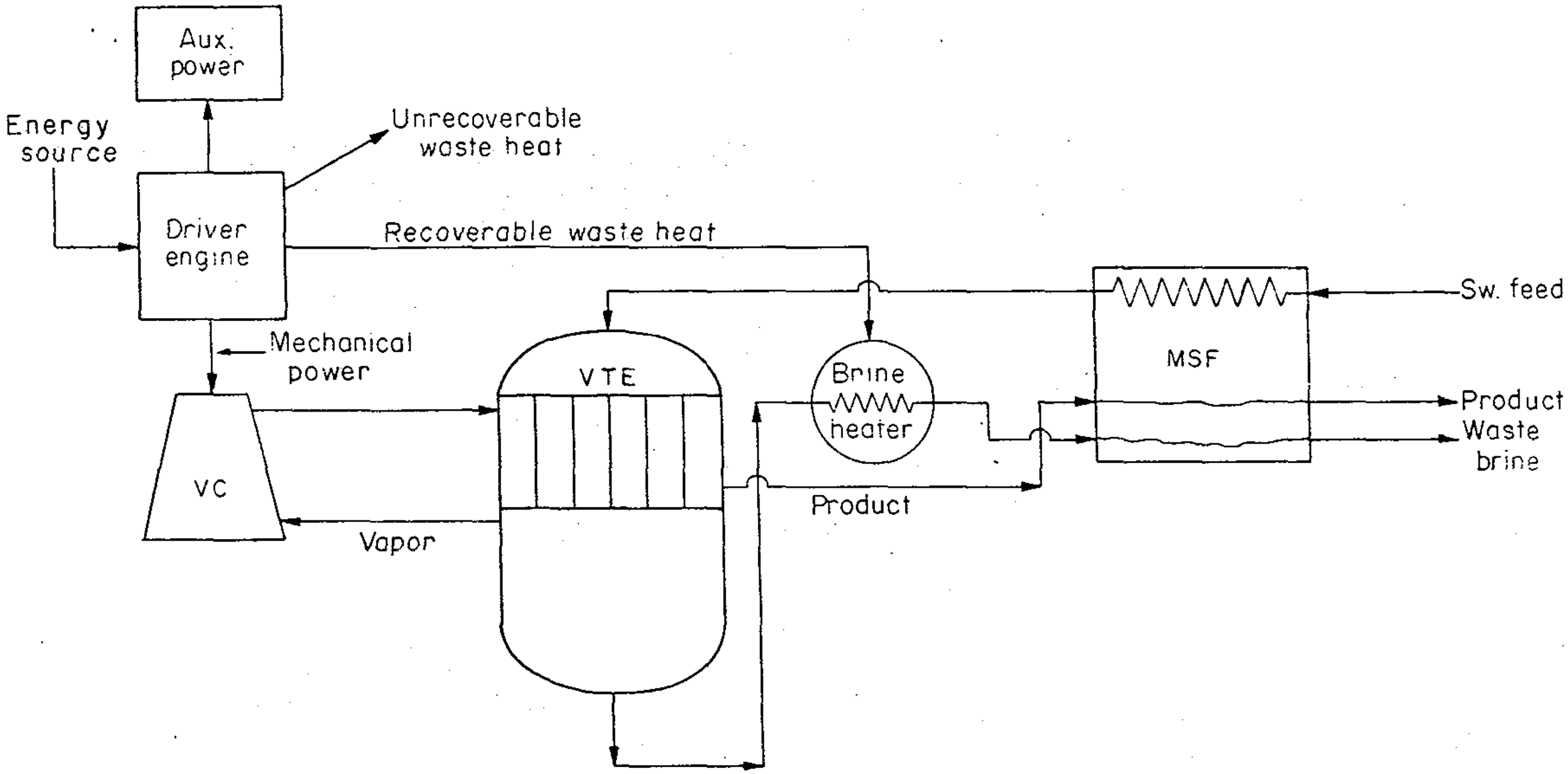
MULTISTAGE FLASH DISTILLATION PLANT SCHEMATIC



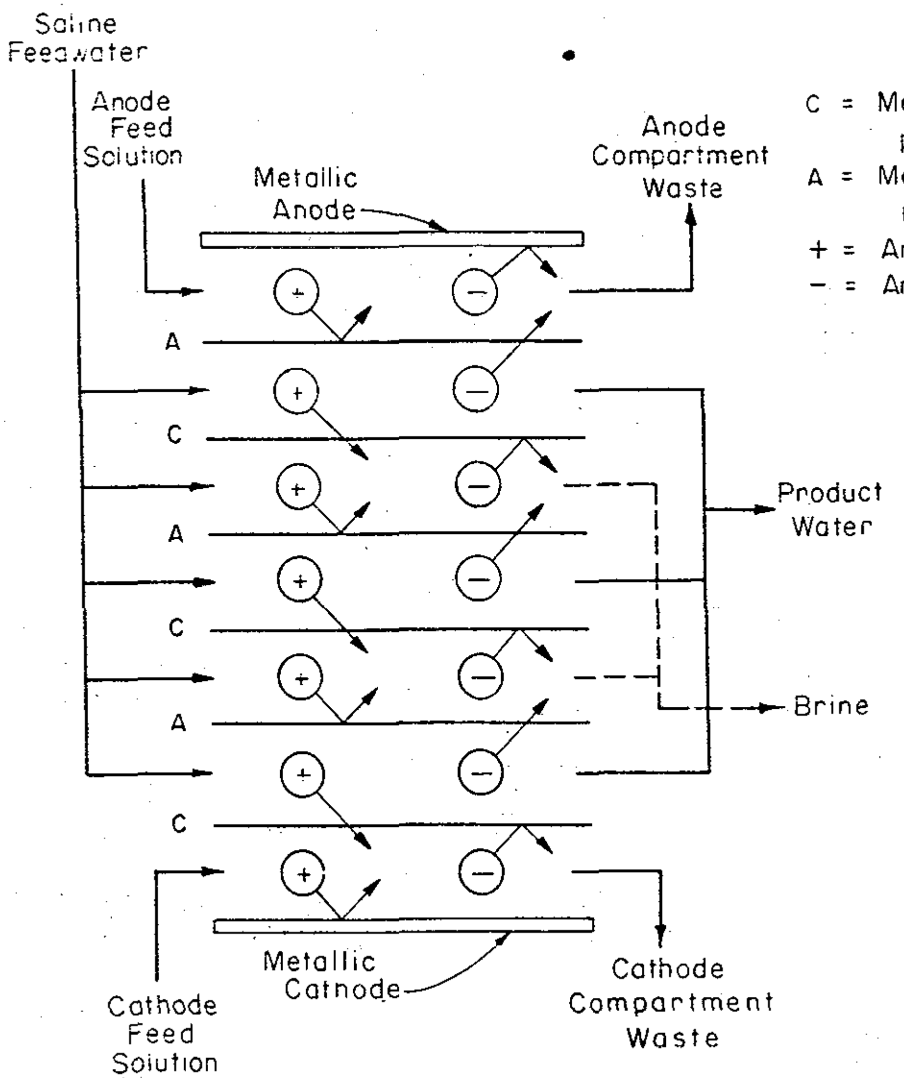
TRIPLE EFFECT VTE DISTILLATION PLANT SCHEMATIC



COMBINATION VTE-MSF DISTILLATION PROCESS



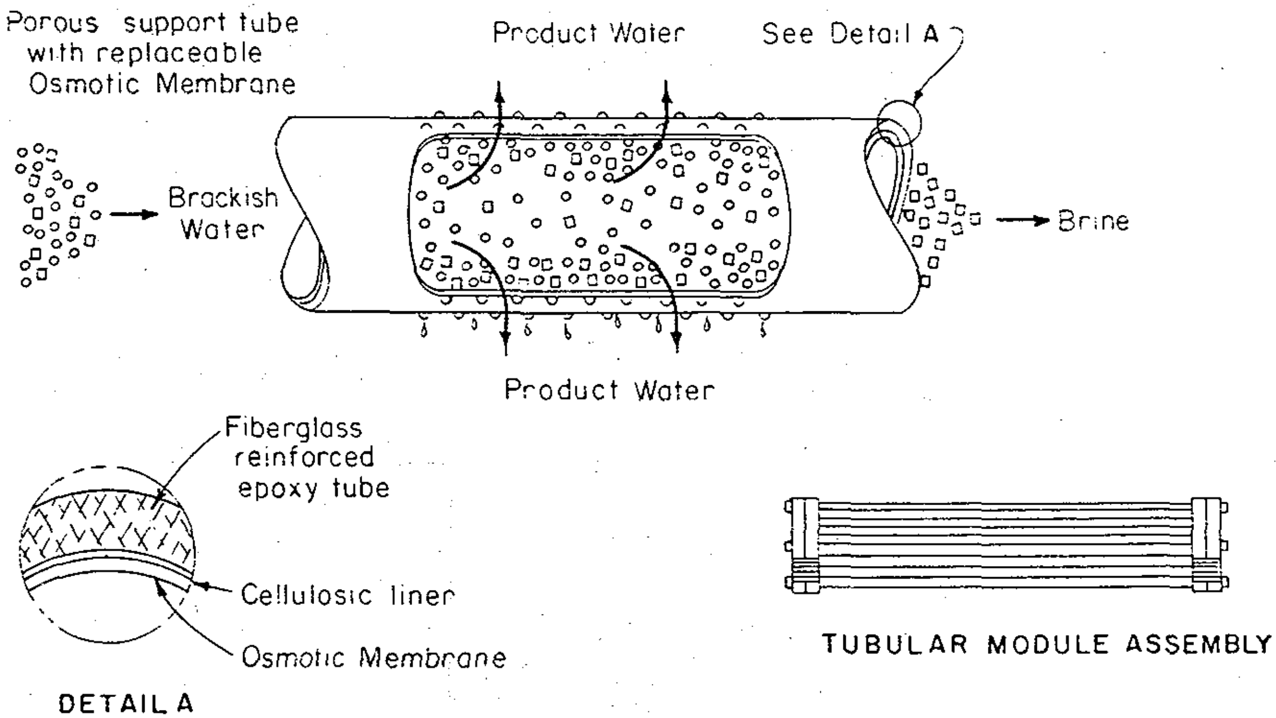
VAPOR COMPRESSOR – VERTICAL TUBE EVAPORATOR PLANT
FEED PRE-HEATED BY ONCE-THRU MSF



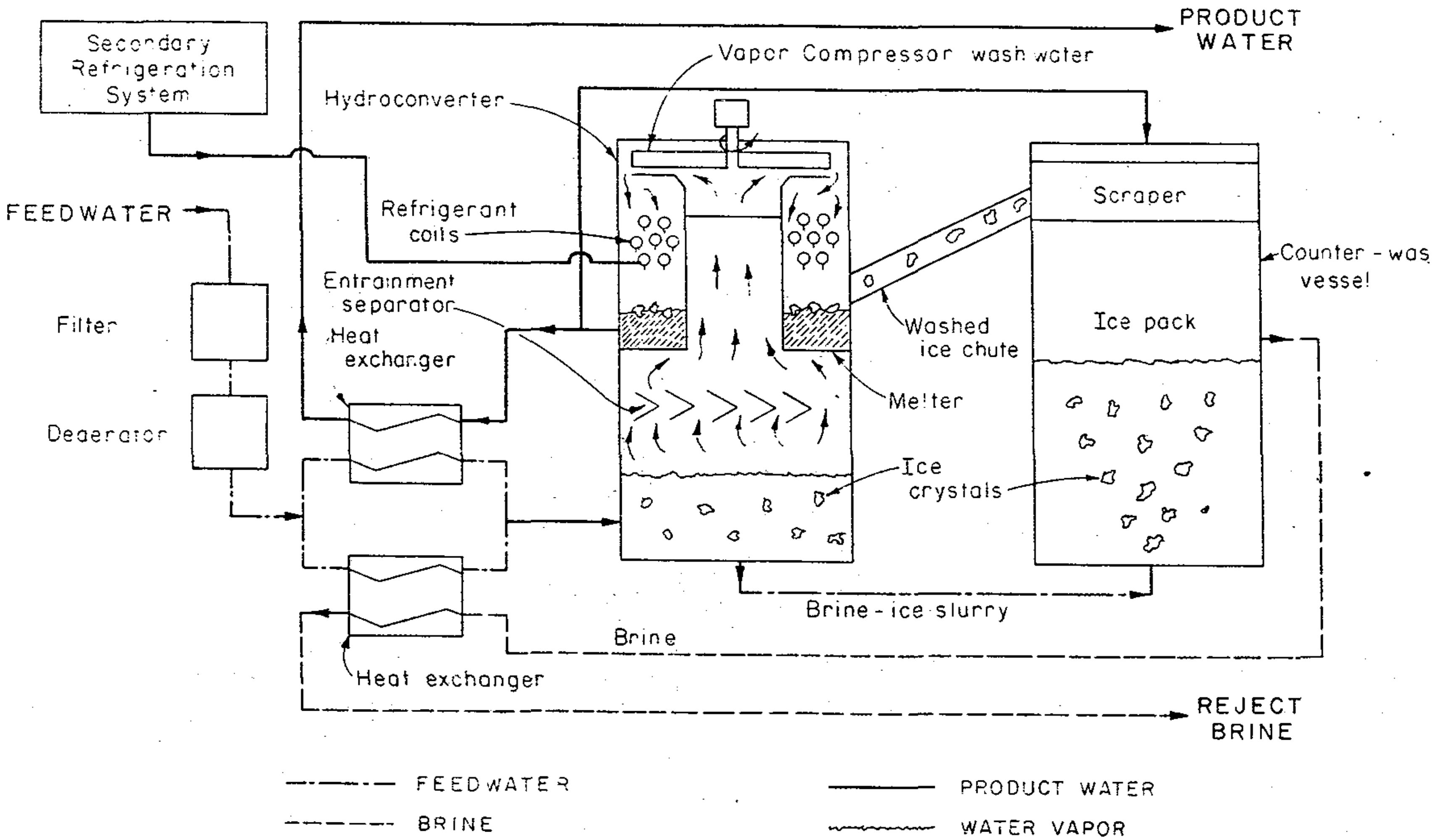
LEGEND

C = Membrane permeable to positive ions only.
A = Membrane permeable to negative ions only.
+ = Any positive ion, such as Na^+
− = Any negative ion, such as Cl^-

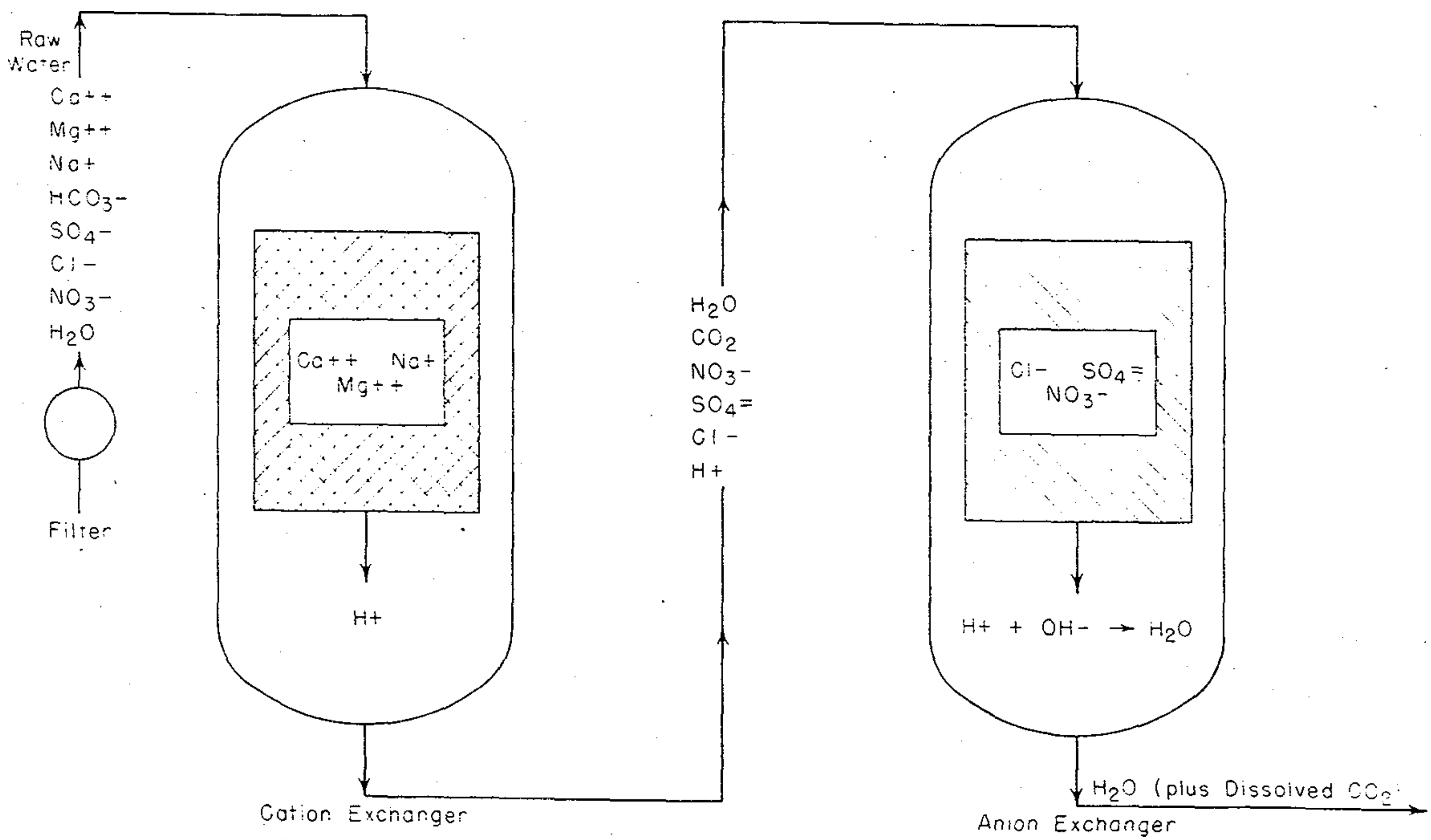
ELECTRODIALYSIS STACK SCHEMATIC



RO TUBULAR MODULE CONFIGURATION



VACUUM FREEZING – VAPOR COMPRESSION PLANT SCHEMATIC



ION EXCHANGE TWO-BED FLOWSHEET

APPENDIX B

BASIS OF COST ESTIMATES

BASIS OF COST ESTIMATES

General

The unit costs of items comprising the proposed alternatives have been developed from an update of prior engineering reports, analysis of recent studies for supplying water to the Aquidneck Island area, evaluation of construction costs for similar projects, and other supplementary cost estimating information. Cost estimates prepared for the various alternatives outlined in this report are considered of sufficient accuracy and order of magnitude that the alternatives can be evaluated. The cost estimates were derived by separating the alternatives into their major cost components and costing these components using the generalized prices presented in this appendix.

Construction Cost Index

Construction cost estimates were based upon the construction cost index compiled and published by Engineering News Record (ENR). An ENR construction cost index of 2440 (July 1976) was chosen as the basis for cost estimates presented in this report.

Pipeline Costs

Cost estimates for transmission mains, both on land and for subaqueous crossings are shown in the following table. The costs include the price of pipe, transportation, excavation, installation, backfilling, and testing, and have been estimated based on trench conditions assumed to be encountered at the various sites.

Item Description	Unit	Unit Cost
Land installations:		
20 inch	lin. feet	$ 50
24 inch	lin. feet	60
30 inch	lin. feet	70
36 inch	lin. feet	80
Subaqueous crossings:		
24 inch	lin. feet	550
30 inch	lin. feet	570
36 inch	lin. feet	590

Pumping Stations

Pumping station costs include all stations on transmission mains and at water treatment facilities. Generalized estimating procedures relating construction costs to installed horsepower were utilized in this study and ranged from $630,000 to $1,186,000 depending upon station design capacity. The costs include estimates for complete installation of pumping units, electrical equipment, and structures to house the equipment.

Groundwater Development Costs

Construction costs for development of groundwater supplies include the cost of exploratory and test wells, production wells complete with screens, casings, pumps, structure, controls, electrical equipment, and well-field interconnecting pipelines. The construction cost was related to well-field capacity and is estimated at $180,000 per million gallons per day capacity. Cost of transmission facilities connecting individual groundwater aquifers is not included in above unit cost.

Big River Reservoir Complex

Preliminary engineering estimates of the cost for constructing the proposed Big River Reservoir and related facilities were obtained from the Rhode Island Water Resources Board. These estimates were based upon anticipated costs as of April 1976, and resulted as follows:

Item	Construction Cost
Roads and Relocations	$ 4,500,000
Aqueduct	18,900,000
Treatment Facilities	27,500,000
Reservoir and Dam	14,000,000
Sub Total	$64,900,000
Engineering and Design	$ 4,520,000
Supervision and Administration	4,618,000
Estimated Total Project Cost	$74,038,000*

*Does not include an estimated $7.3 million for land aquisition, condemnation, etc.

Disinfection Facilities

The construction cost of disinfection facilities included in the development of groundwater supplies was estimated in relation to design capacity in million gallons per day. For purposes of this study, the estimated construction cost is $33,000 per million gallons per day capacity.

Operation and Maintenance Costs

The operation and maintenance costs for components of alternative water supply systems were based upon a percentage of the construction cost of such components. Percentages adopted for this study are as follows:

Component	Percentage of Construction Cost
Transmission Mains and Aqueduct	1.0
Treatment Facilities	17.0
Groundwater Facilities	2.0
Pumping Stations:	
Structures	2.0
Equipment	5.0
Dams and Reservoir	0.1

Energy:

Pump operation $150 per year per horsepower

First Costs and Annual Costs

All estimated project costs include an allowance of 20 percent of construction costs for contingencies and unforeseen conditions. The costs for engineering and design and supervision and administration are based upon a report to the Committee on Appropriation of the House of Representatives, United States Congress entitled "Civil Works Costs for Engineering and Design and Supervision and Administration."

Average annual costs for the proposed alternatives are based upon an interest rate of 6 3/8 percent and amortization of investment costs over the useful life of the component considered.